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Public Utility Commission of Texas

Memorandum

TO: Chairman Peter M. Lake
Commissioner Will McAdams
Commissioner Lori Cobos
Commissioner Jimmy Glotfelty

FROM: Connie Corona, Deputy Executive Director

DATE: August 11, 2021

RE: Work Session for August 12, 2021 – Project 52268 & 51840

Attached are the slides for the Work Session being held on August 12, 2021.

Texas Climate Hazards

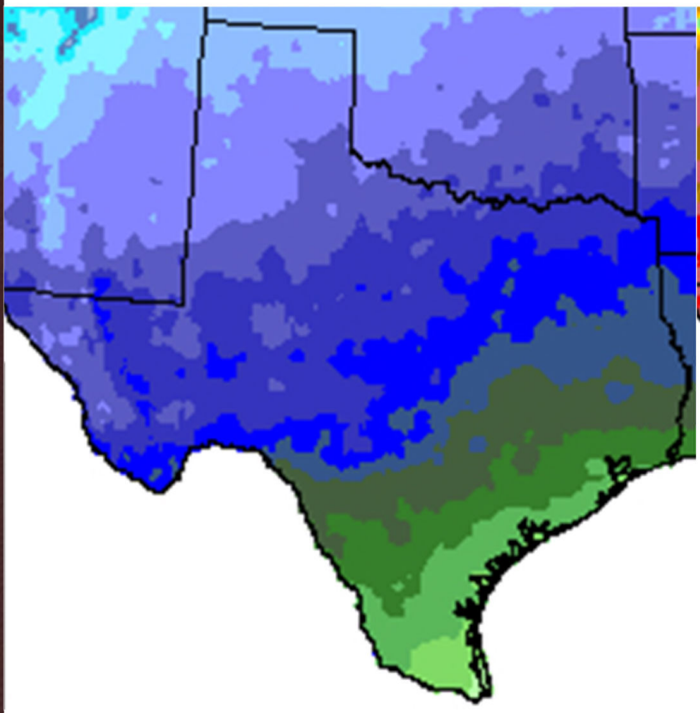
John W. Nielsen-Gammon
Texas State Climatologist
Department of Atmospheric Sciences

Outline

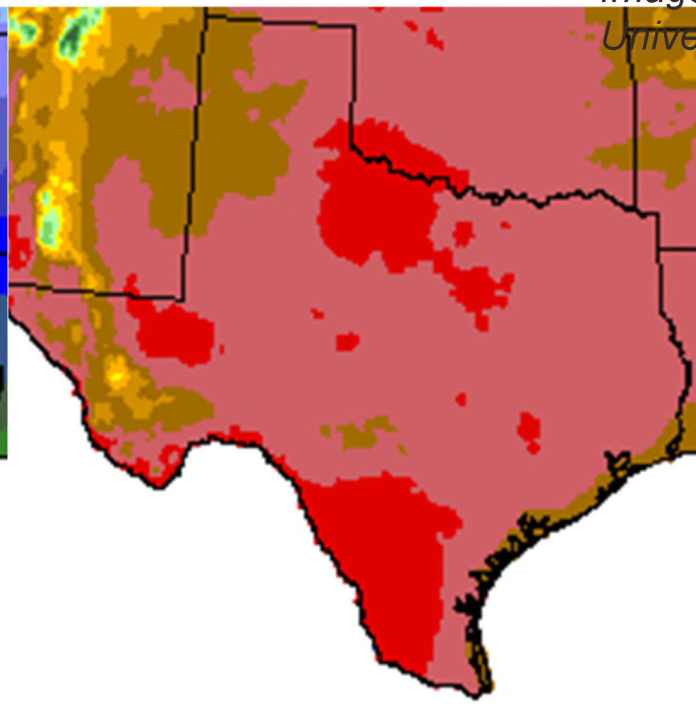
- Texas climate overview
- Texas climate hazards
- Texas climate hazard trends
- Estimating Texas climate hazard return periods
- How unusual was Feb. 2021: a warning

Texas Climate at a Glance

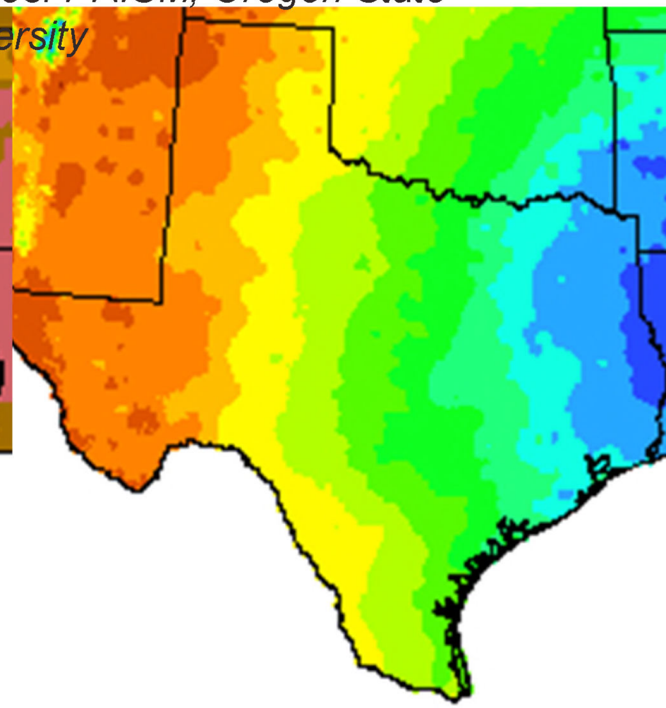
Images: PRISM, Oregon State University



Normal January Daily Minimum Temperature



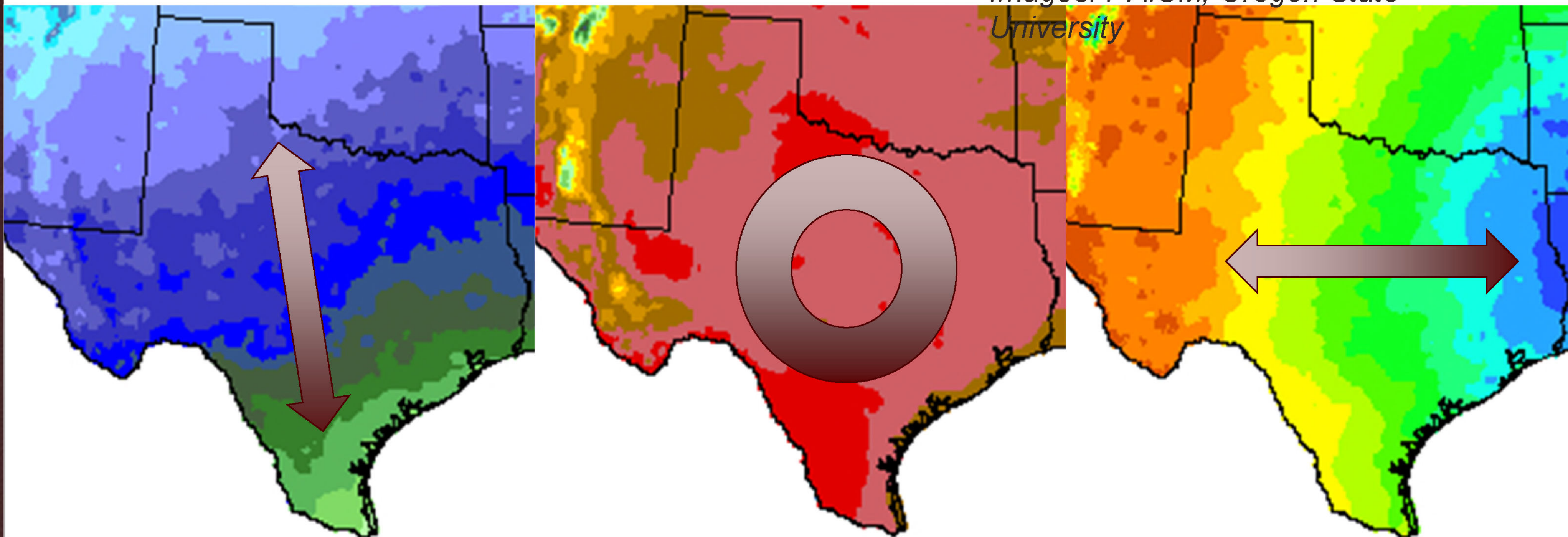
Normal July Daily Maximum Temperature



Normal February Precipitation

Texas Climate at a Glance

Images: PRISM, Oregon State University



Normal January Daily Minimum Temperature

Normal July Daily Maximum Temperature

Normal February Precipitation

Texas climate hazards

- Extreme heat
- Extreme cold
- Frozen precipitation
- Windstorms
- Droughts
- Floods

Texas climate hazard trends: How do you tell???

- Is there a trend in the historical data?
- Do climate models simulate and project a trend?
- Is there sound scientific understanding of the reason for a trend?

Texas climate hazard trends: How do you tell???

- Is there a trend in the historical data?
- Do climate models simulate and project a trend?
- Is there sound scientific understanding of the reason for a trend?
- *In honor of the Olympics, I'll award a maximum of ten points for each scoring category…*

Texas climate hazards

• Extreme heat	Getting worse: 25/30
• Extreme cold	Getting better: 28/30
• Frozen precipitation	Getting better: 19/30
• Windstorms	Getting worse: 10/30
• Droughts	It depends…
• Floods	It depends…

Texas climate hazards

• Extreme heat	Getting worse: 25/30
• Extreme cold	Getting better: 28/30
• Frozen precipitation	Getting better: 19/30
• Windstorms	Getting worse: 10/30
~~• Droughts~~ Low flows	Getting worse: 20/30
~~• Floods~~ Heavy rain	Getting worse: 24/30

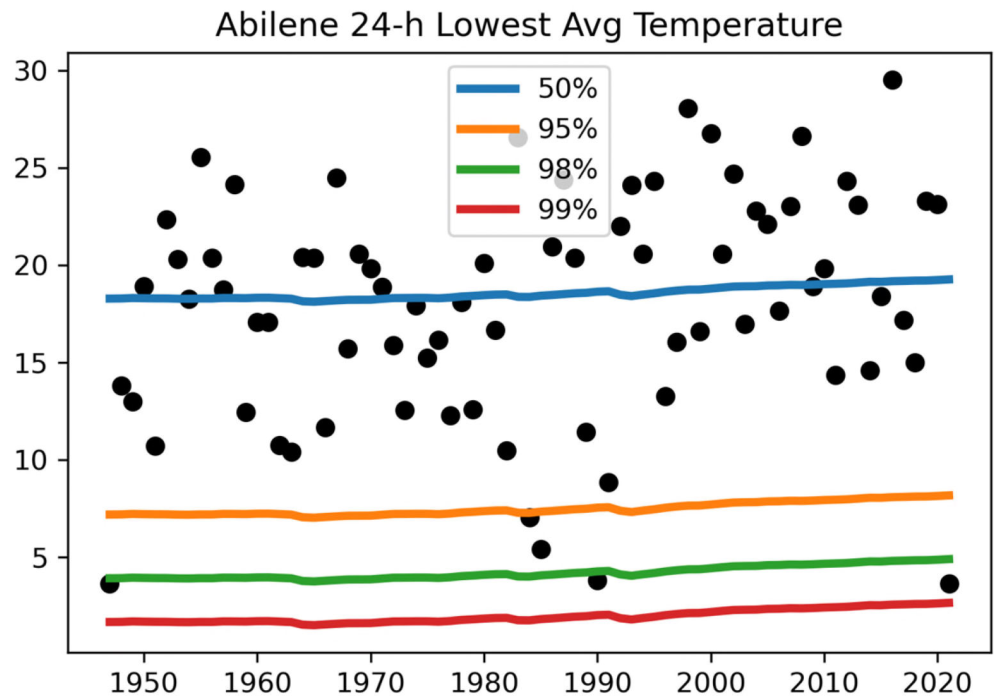
Estimating Texas climate hazard return periods: technical details

- Hourly and daily data
- Missing data, differing observation times
- Operationally relevant hazard definitions
- Annual block maxima
- Stationary and nonstationary GEV with covariate (GMST)
- **95%, 98%, 99% probability of non-occurrence in a given year**
  - **Same as 5%, 2%, 1% chance in a given year (but which year?)**

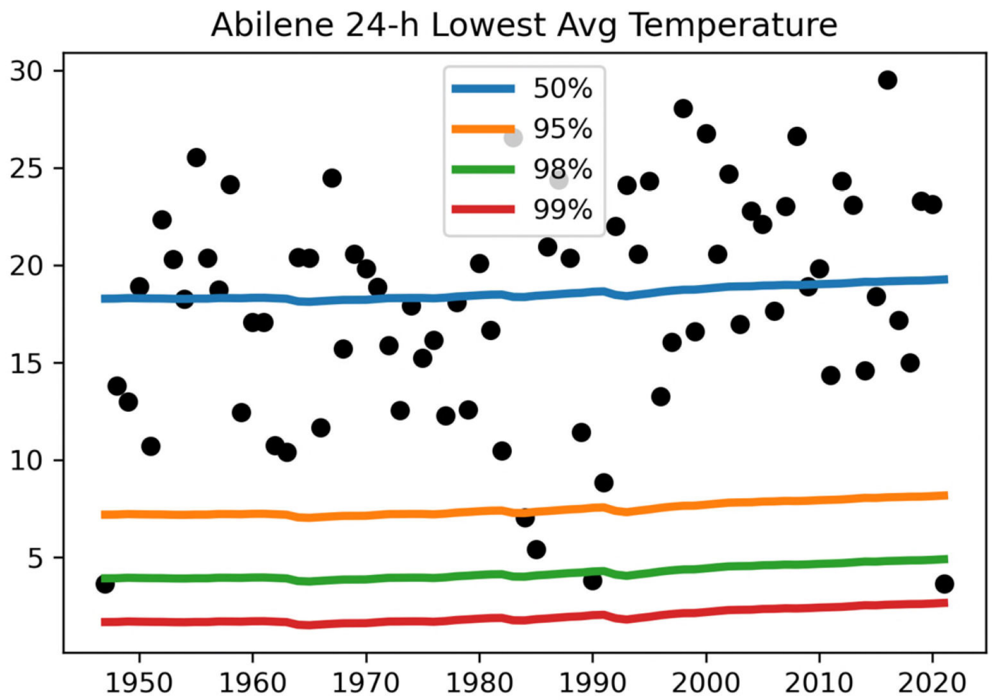
Sample winter hazard parameters

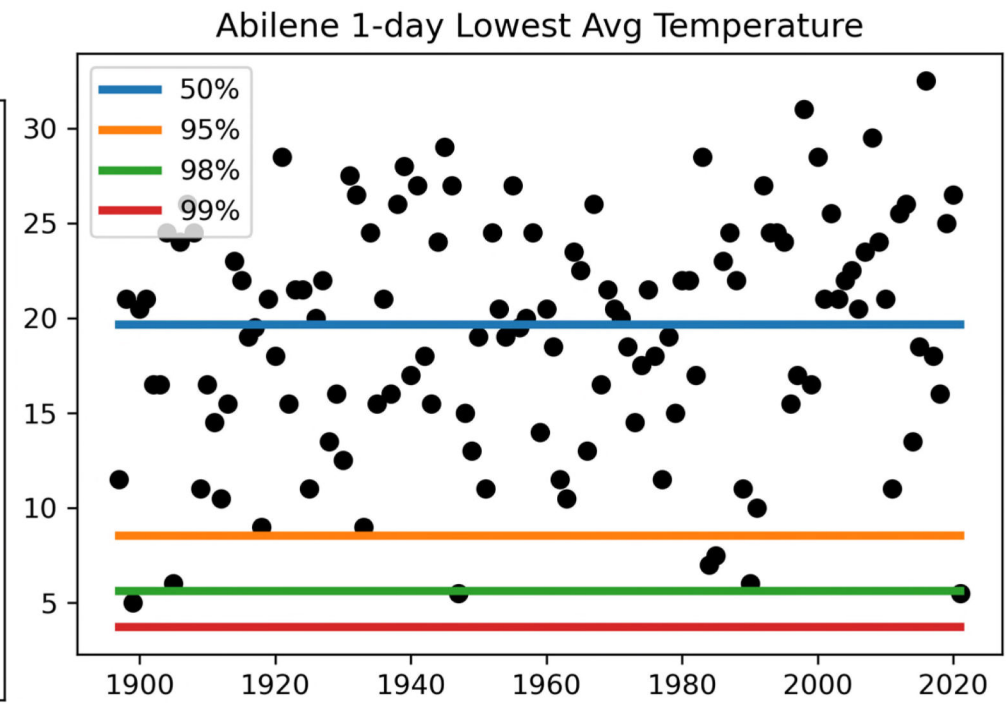
- Minimum temperature
- Lowest daily average temperature
- Lowest average temperature over N hours/days
- Maximum freezing hours
- Lowest temperature with precipitation
- Lowest average temperature without sun
- Lowest average temperature with wind

Example: Abilene

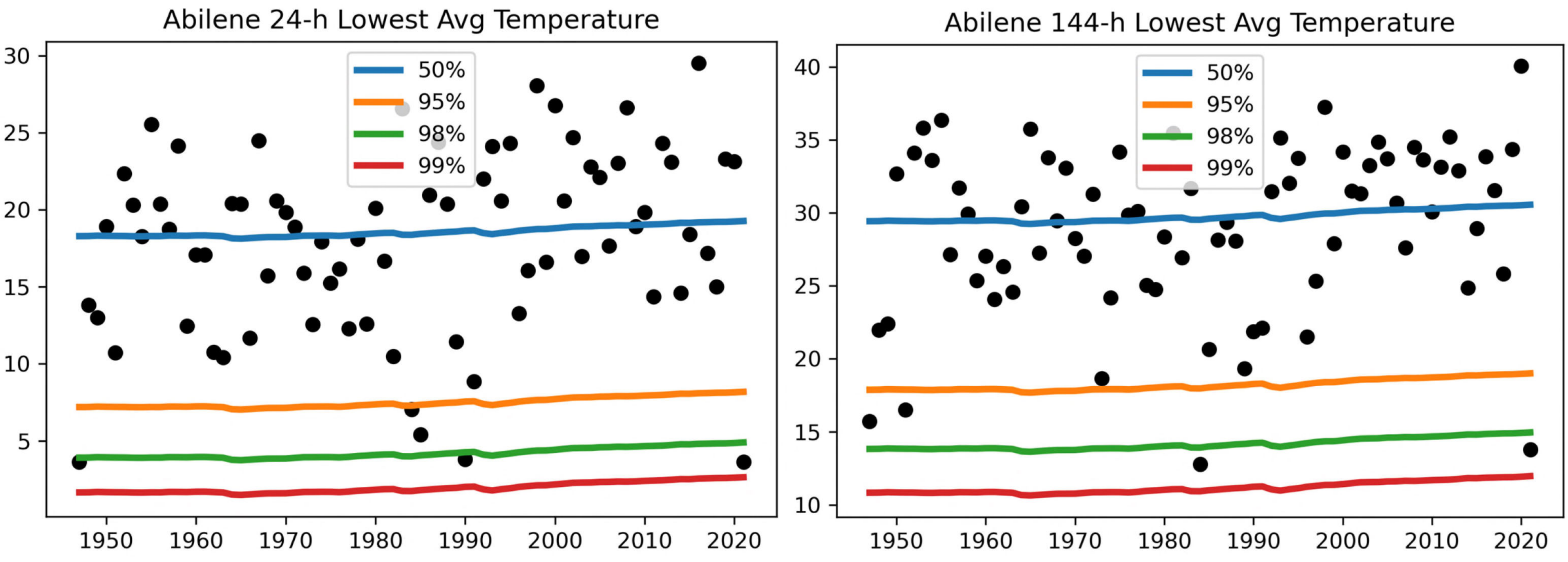


Example: Abilene

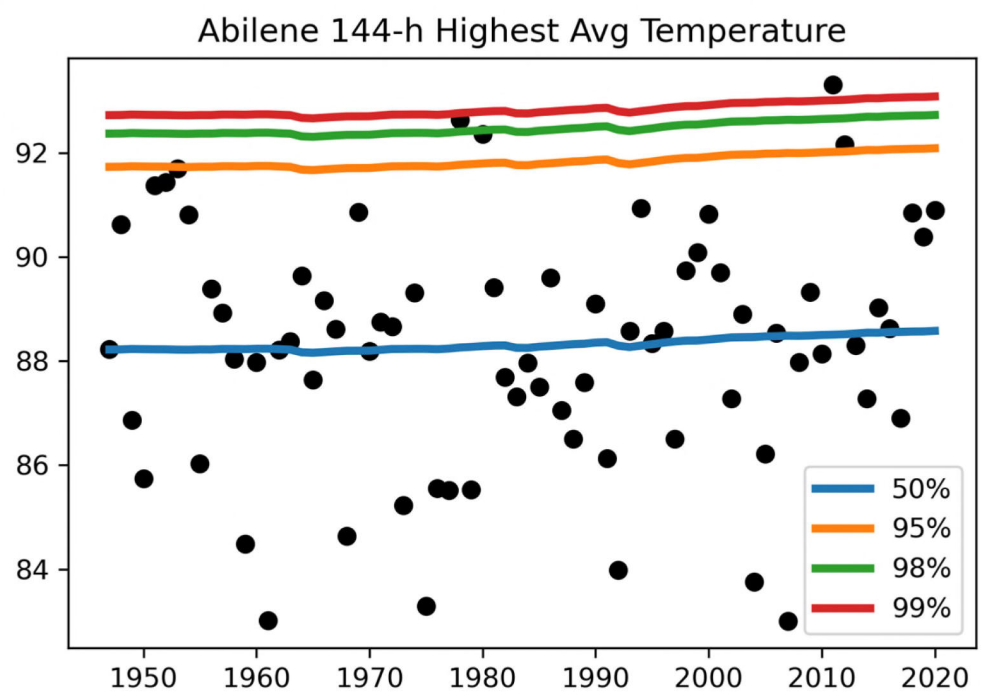


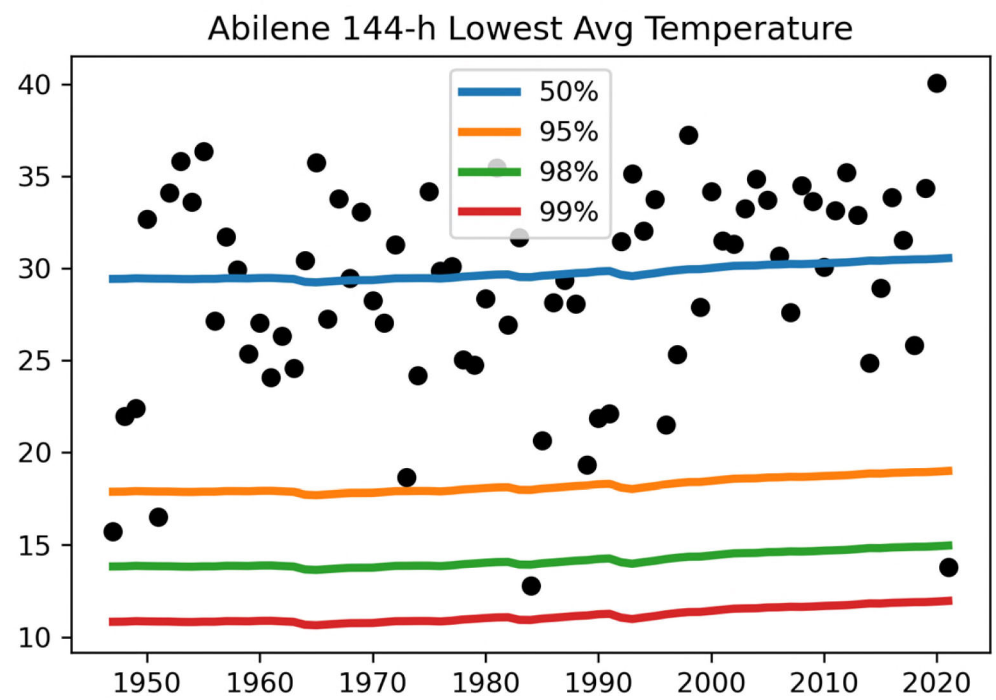


Example: Abilene



Example: Abilene





How does Feb 2021 rank in Texas?

- 1-Day Min: 1899, 1930, 1989, 1951, **2021**
- 1-Day Max: 1899, 1962, 1983, 1989, **2021**
- 1-Day Avg: 1899, 1989, **2021**, 1983, 1962

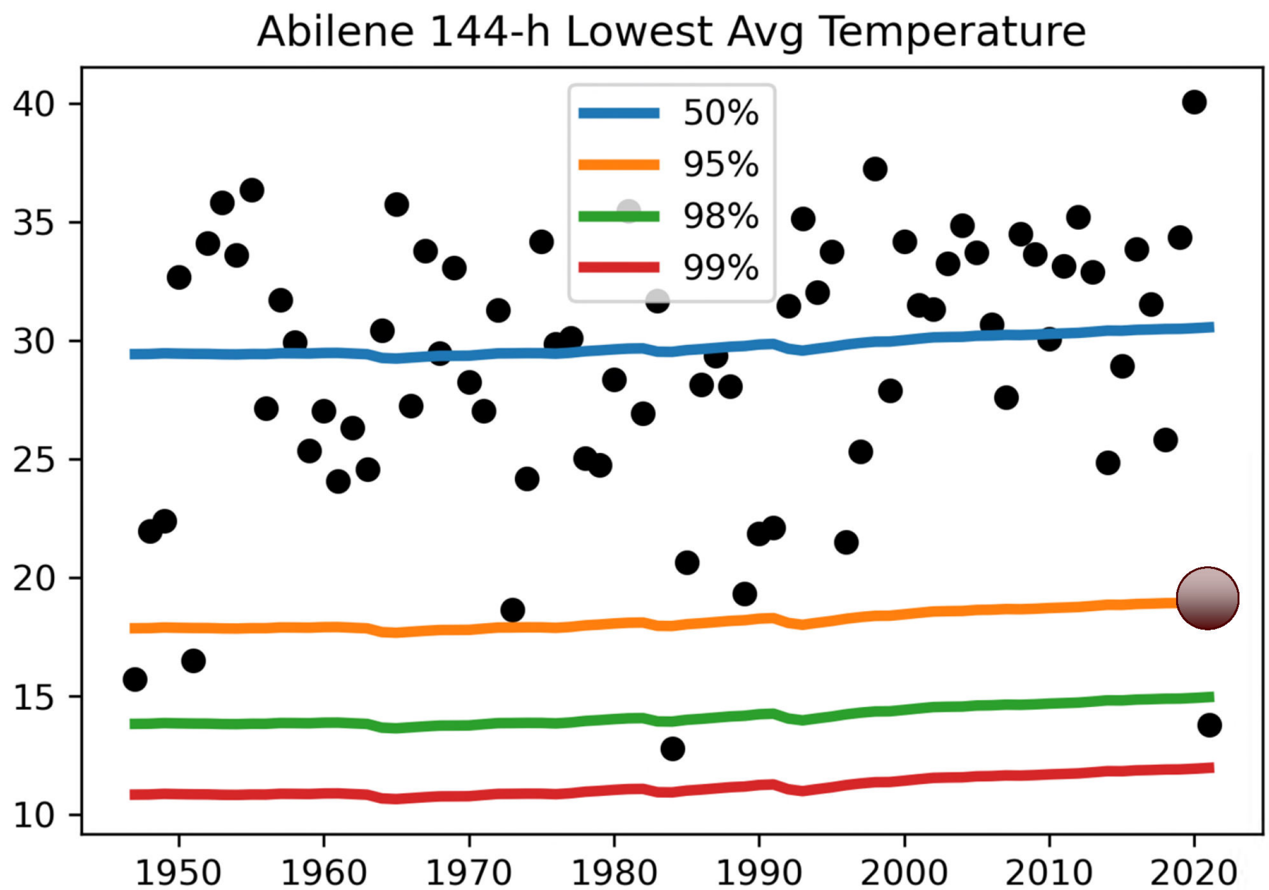
- 7-Day Min: 1899, 1983, 1930, 1951, 1940
- 7-Day Max: 1983, **2021,** 1947, 1973, 1895
- 7-Day Avg: 1983, 1899, **2021,** 1930, 1940

How does Feb 2021 rank in Oklahoma?

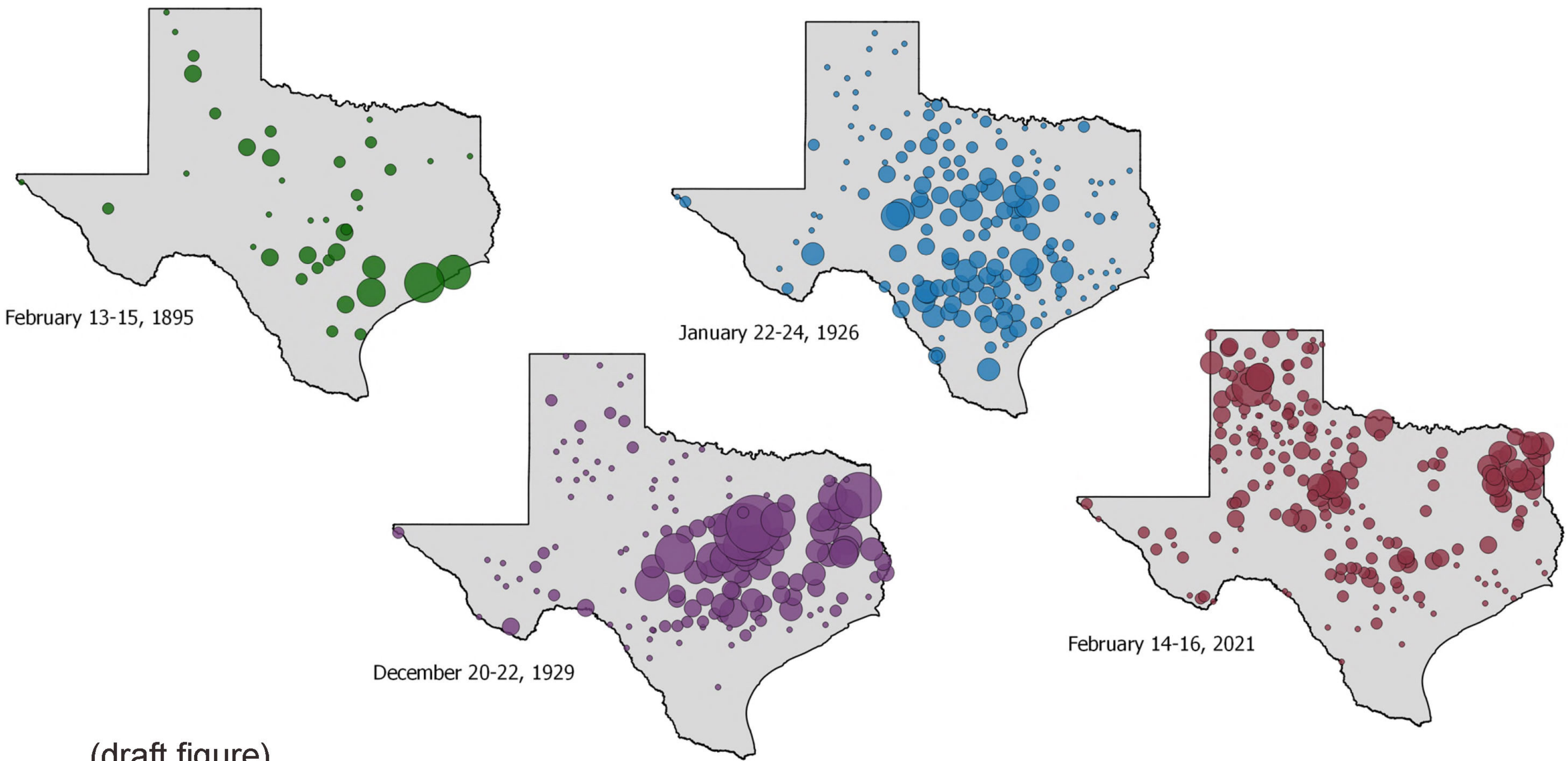
- 1-Day Min: **2021,** 1905
- 1-Day Max: **2021,** 1983
- 1-Day Avg: **2021,** 1899

- 7-Day Min: **2021,** 1899
- 7-Day Max: **2021,** 1983
- 7-Day Avg: **2021,** 1983

Grid Crisis Timing



Also: Winter Precipitation



(draft figure)

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Texas Climate 101:
Winter Temperature Extremes

Chris Coleman
ERCOT Senior Meteorologist

PUC Work Session
August 12, 2021

Summary of Winter Weather Extremes in Texas

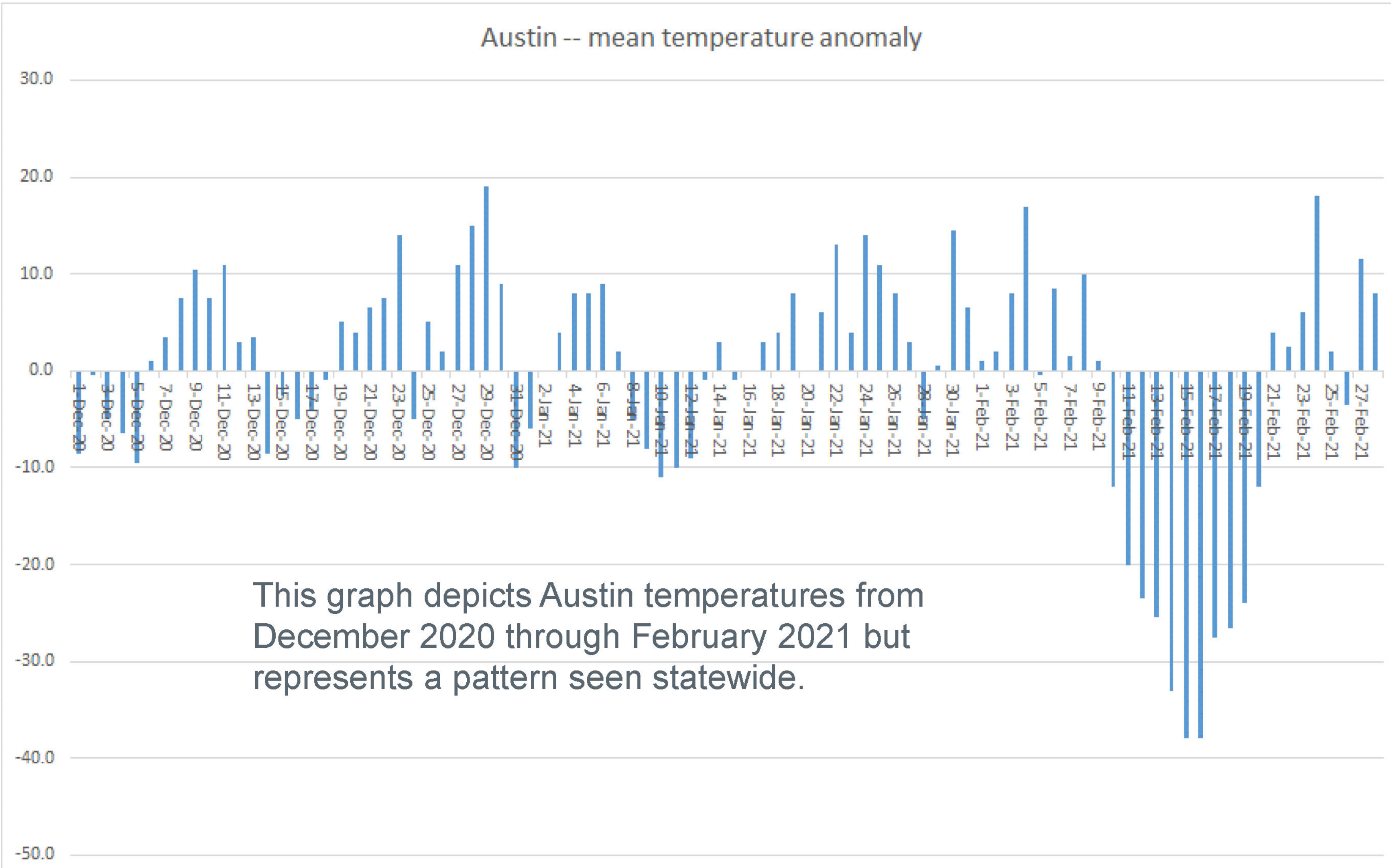
- Periods of extreme winter temperatures similar to what impacted the Texas power grid in February 2021 are rare, and the coldest extremes do not necessarily coincide with a cold winter overall.

- Since the 1890s (over 120 years), there have only been five winters in Texas with extreme, prolonged cold temperatures impacting the entire region, including February 2021.

- Until February 2021, it had been 31 years since the Texas power grid experienced a period of extreme, prolonged cold temperatures.

- The most extreme winter periods typically have consecutive days of cold build up and are driven largely by a combination of low temperatures across the region's largest urban load centers.
  - Today's presentation considers extreme cold periods in Dallas, Houston, Austin, Abilene (representation of West Texas) and Brownsville (representation of South Texas).

Mild Winters Can Have Periods of Extreme Cold



This graph depicts Austin temperatures from December 2020 through February 2021 but represents a pattern seen statewide.

Dallas and Houston Extremes

- In **Dallas**, there were 14 winters dating back to 1899 that recorded a low of 5 degrees or colder.
  - During every decade from the 1890s through the 1990s, Dallas had at least two winters with temperatures that were 10 degrees or colder.
  - Temperatures never dropped to 10 degrees or colder between 1997 and 2020.
  - Coldest temperature in 2011 was 13 degrees.
- In **Houston**, there were 14 winters dating back to 1895 that recorded a low of 15 degrees of colder.

Dallas

2021 (40)	1933 (43)
1989 (71)	1930 (40)
1983 (7)	1918 (11)
1964 (5)	1912 (6)
1949 (52)	1911 (119)
1947 (31)	1905 (2)
1943 (95)	1899 (1)

Houston

2021 (40)	1933 (43)
1989 (71)	1930 (40)
1983 (7)	1918 (11)
1982 (54)	1912 (6)
1951 (62)	1905 (2)
1949 (52)	1899 (1)
1940 (21)	1895 (?)

Figures in parenthesis represent the rankings for the coldest Texas winters, with 1 being the coldest.

Years highlighted in blue represent the top 11 coldest years on record.

Most Extreme Winter Periods

- The worst periods of extreme, prolonged cold impacting the entire ERCOT region occurred in **2021, 1989, 1983, 1930 and 1899**.

- Dallas recorded temperatures of 5 degrees or colder and Houston recorded temperatures of 15 degrees or colder during winters occurring in: 2021, 1989, 1983, 1949, 1933, 1930, 1918, 1912, 1905 and 1899.

- Using the 10 coldest periods in Dallas and Houston as a baseline, these other cities also recorded extreme cold temperatures during some of the same years:
  - Austin recorded a temperature of 12 degrees or colder in 2021, 1989, 1983, 1949, 1933, 1930, 1918 and 1899.
  - Abilene recorded a temperature of 2 degrees or colder in 2021, 1989, 1983, 1933, 1930, 1918 and 1899.
  - Brownsville recorded a temperature of 23 degrees or colder in 2021, 1989, 1983 and 1899.

(Temperature thresholds were determined to get between 10 and 15 years.)

Appendix

Dallas Historical Extreme Cold Comparisons

2021		
Dallas	max tmp	min tmp
9-Feb-21	39	30
10-Feb-21	**31**	28
11-Feb-21	**29**	24
12-Feb-21	**26**	21
13-Feb-21	33	20
14-Feb-21	**22**	**9**
15-Feb-21	**14**	**4**
16-Feb-21	**18**	**-2**
17-Feb-21	**27**	18
18-Feb-21	**31**	22
19-Feb-21	40	15
20-Feb-21	56	22

8 of 9 days didn't get above Freezing
****
3 days with lows in the single digits or below

2011		
Dallas	max tmp	min tmp
1-Feb-11	38	**14**
2-Feb-11	**20**	**13**
3-Feb-11	**23**	**17**
4-Feb-11	**29**	**19**
5-Feb-11	54	**17**
6-Feb-11	54	35
7-Feb-11	49	32
8-Feb-11	56	29
9-Feb-11	47	**16**
10-Feb-11	36	**15**
11-Feb-11	55	20

2011 doesn't measure up with the most extreme events (however wind chill was a significant factor)

1989		
Dallas	max tmp	min tmp
12-Dec-89	40	**18**
13-Dec-89	58	**18**
14-Dec-89	63	29
15-Dec-89	40	**14**
16-Dec-89	**27**	**12**
17-Dec-89	35	24
18-Dec-89	36	30
19-Dec-89	38	22
20-Dec-89	42	**17**
21-Dec-89	**29**	**12**
22-Dec-89	**14**	**3**
23-Dec-89	**22**	**-1**
24-Dec-89	42	**13**
25-Dec-89	68	21

As a whole 1989 was not nearly as cold as 1983, but there were two mornings with colder extremes

1983		
Dallas	max tmp	min tmp
18-Dec-83	36	18
19-Dec-83	**20**	16
20-Dec-83	**31**	18
21-Dec-83	**29**	**10**
22-Dec-83	**15**	**5**
23-Dec-83	**19**	11
24-Dec-83	**13**	**7**
25-Dec-83	**18**	**6**
26-Dec-83	**29**	16
27-Dec-83	**31**	25
28-Dec-83	**31**	18
29-Dec-83	**28**	**10**
30-Dec-83	35	**7**
31-Dec-83	49	17

9 Consecutive Days (and 13 of 14) with lows in the teens or Colder
****
11 Consecutive days with sub-freezing Highs
****
4 days with lows in the single digits

1949	actual temperatures	
Dallas	max tmp	min tmp
28-Jan-49	36	16
29-Jan-49	22	14
30-Jan-49	**20**	**8**
31-Jan-49	**30**	**-2**
1-Feb-49	37	14

1933		
Dallas	max tmp	min tmp
7-Feb-33	57	**7**
8-Feb-33	**22**	**2**
9-Feb-33	**31**	11
10-Feb-33	30	20
11-Feb-33	37	16

1930	actual temperatures	
Dallas	max tmp	min tmp
8-Jan-30	35	22
9-Jan-30	**30**	19
10-Jan-30	**28**	16
11-Jan-30	40	22
12-Jan-30	44	33
13-Jan-30	45	35
14-Jan-30	40	29
15-Jan-30	35	17
16-Jan-30	**31**	11
17-Jan-30	**24**	**2**
18-Jan-30	**30**	**-1**
19-Jan-30	**32**	14
20-Jan-30	**32**	28
21-Jan-30	**32**	12
22-Jan-30	**31**	**8**
23-Jan-30	44	17

8 of 9 days with lows in the teens or Colder
****
7+ Consecutive days when the high didn't get above freezing

Dallas Historical Extreme Cold Comparisons

2021		
Dallas	max tmp	min tmp
9-Feb-21	39	30
10-Feb-21	**31**	28
11-Feb-21	**29**	24
12-Feb-21	**26**	21
13-Feb-21	33	20
14-Feb-21	**22**	**9**
15-Feb-21	**14**	**4**
16-Feb-21	**18**	**-2**
17-Feb-21	**27**	18
18-Feb-21	**31**	22
19-Feb-21	40	15
20-Feb-21	56	22

8 of 9 days didn't get above freezing
****
3 days with lows in the single digits or below

1912	actual temperatures	
Dallas	max tmp	min tmp
6-Jan-12	45	11
7-Jan-12	**27**	**6**
8-Jan-12	30	15
9-Jan-12	52	15
10-Jan-12	58	34
11-Jan-12	52	**9**
12-Jan-12	**19**	**1**
13-Jan-12	**30**	**7**
14-Jan-12	63	16

1918	actual temperatures	
Dallas	max tmp	min tmp
10-Jan-18	47	12
11-Jan-18	**19**	**4**
12-Jan-18	33	**4**
13-Jan-18	42	15
14-Jan-18	41	28
15-Jan-18	53	24
16-Jan-18	51	26
17-Jan-18	45	31
18-Jan-18	46	25
19-Jan-18	44	26
20-Jan-18	**29**	21
21-Jan-18	**32**	14
22-Jan-18	44	**6**
23-Jan-18	58	28
24-Jan-18	63	34
25-Jan-18	76	40
26-Jan-18	77	37
27-Jan-18	37	21
28-Jan-18	36	19
29-Jan-18	43	21
30-Jan-18	43	18
31-Jan-18	**29**	14
1-Feb-18	**26**	12
2-Feb-18	50	17

Prolonged stretch with periods of extreme cold interrupted by milder periods

Coldest days:

2/12/1899: -8
1/31/1949: -2
2/16/2021: -2
1/18/1930: -1
1/23/1989: -1

1905	actual temperatures	
Dallas	max tmp	min tmp
12-Jan-05	**26**	18
13-Jan-05	**26**	12
14-Jan-05	**31**	13
15-Jan-05	**32**	11
16-Jan-05	44	23
17-Jan-05	49	37
18-Jan-05	60	42
19-Jan-05	60	35
20-Jan-05	67	40
21-Jan-05	48	34
22-Jan-05	37	30
23-Jan-05	38	31
24-Jan-05	40	27
25-Jan-05	**28**	15
26-Jan-05	38	13
27-Jan-05	55	31
28-Jan-05	48	40
29-Jan-05	46	37
30-Jan-05	42	27
31-Jan-05	47	40
1-Feb-05	41	21
2-Feb-05	**21**	15
3-Feb-05	**19**	14
4-Feb-05	**23**	12
5-Feb-05	**29**	17
6-Feb-05	**25**	15
7-Feb-05	**32**	25
8-Feb-05	48	24
9-Feb-05	47	30
10-Feb-05	47	25
11-Feb-05	48	15
12-Feb-05	**15**	**5**
13-Feb-05	**26**	**1**
14-Feb-05	43	15

13 total days over this prolonged stretch that did not get above freezing

1899		
Dallas	max tmp	min tmp
1899-01-29	40	15
1899-01-30	59	26
1899-01-31	**29**	12
1899-02-01	60	19
1899-02-02	44	40
1899-02-03	38	36
1899-02-04	**28**	24
1899-02-05	**27**	21
1899-02-06	**29**	18
1899-02-07	**31**	14
1899-02-08	49	19
1899-02-09	24	16
1899-02-10	**26**	18
1899-02-11	**16**	**15**
1899-02-12	**12**	**-8**
1899-02-13	35	**4**

February 2, 1899: coldest day on record for Dallas
****
8 Consecutive days with lows in the teens or colder (2/6-2/13)

CenterPoint Energy

Public Utility Commission of Texas

Work Session – August 12, 2021

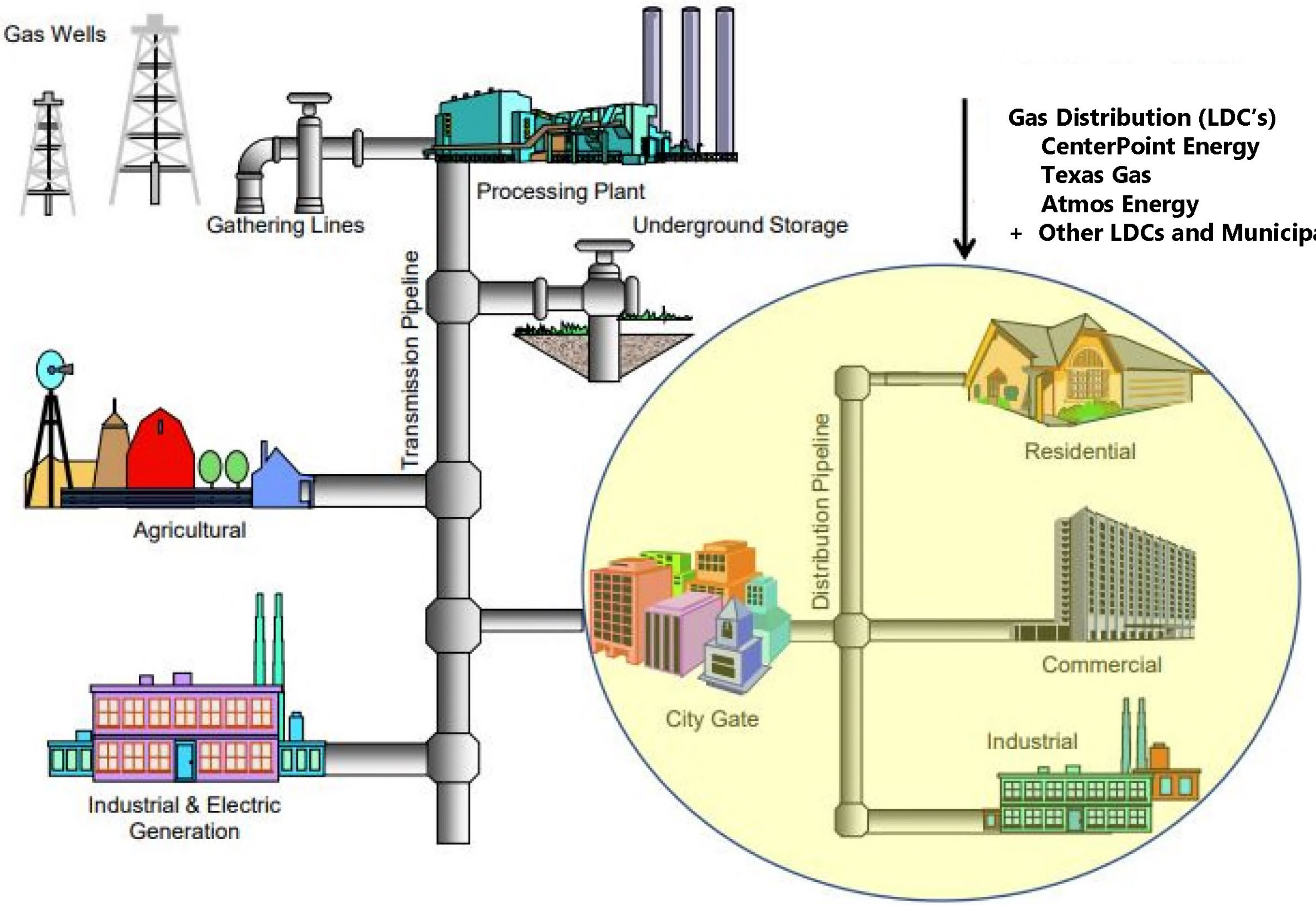
Natural Gas Systems from Wellhead to Burner-Tip

Keith Wall – Director, Regulatory Affairs TX Gas

Jamie Herdocia – Director, Engineering TX Gas

Natural Gas Pipeline Systems from Wellhead to Burner-Tip

CenterPoint Energy



Gas Distribution (LDC's)
- **CenterPoint Energy**
- **Texas Gas**
- **Atmos Energy**
- **+ Other LDCs and Municipal Gas Utilities**

Gas Plant Winterization

Presentation to Public Utilities Commission of Texas

August 12th, 2021

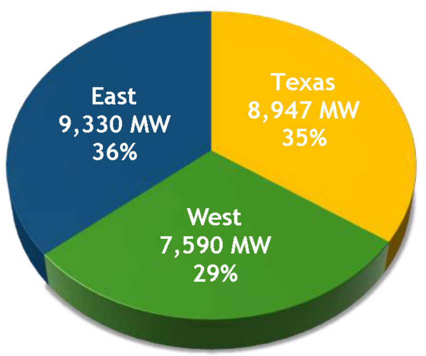
Calpine Corporation - National Portfolio ~26,000 MW

- Geographically diversified portfolio: Scale in America's most competitive power markets
- More than 2,300 employees
- Serve wholesale and retail customers in 22 states, Canada and Mexico
- Largest geothermal power producer in America
- Largest operator of combined heat and power (cogeneration) in America

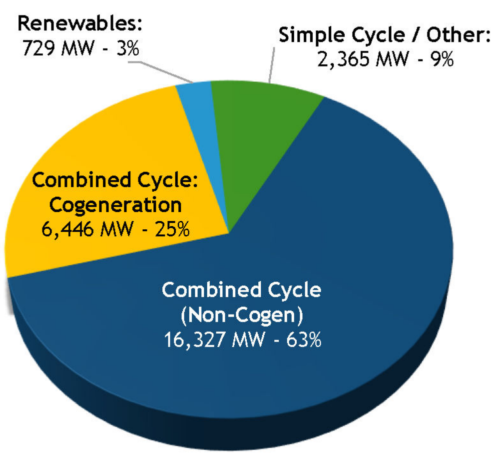
Market	Calpine Rank (MW Gas-Fired Capacity)
Texas	#1
California	#1
New England	#3
Mid-Atlantic	#2

Rankings reflect 2019 MWh

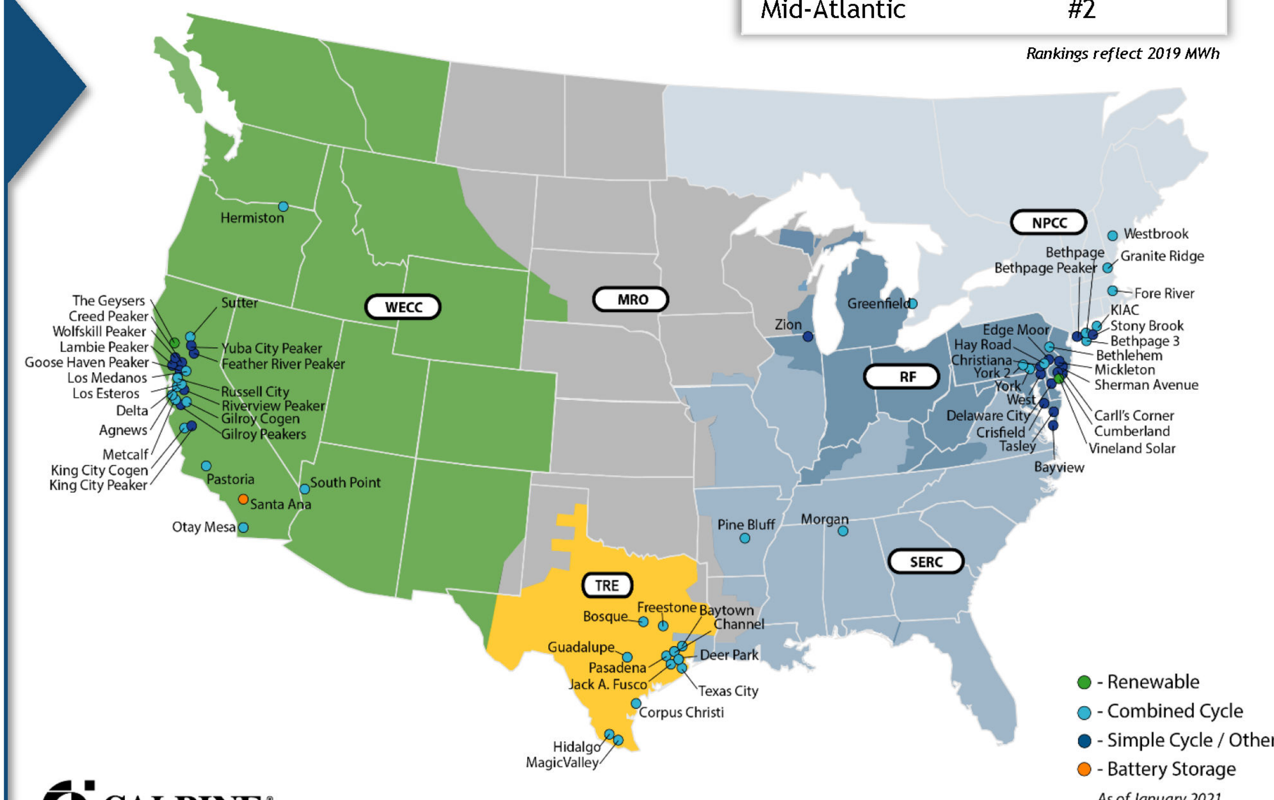
Geographic Diversity



Dispatch Technology



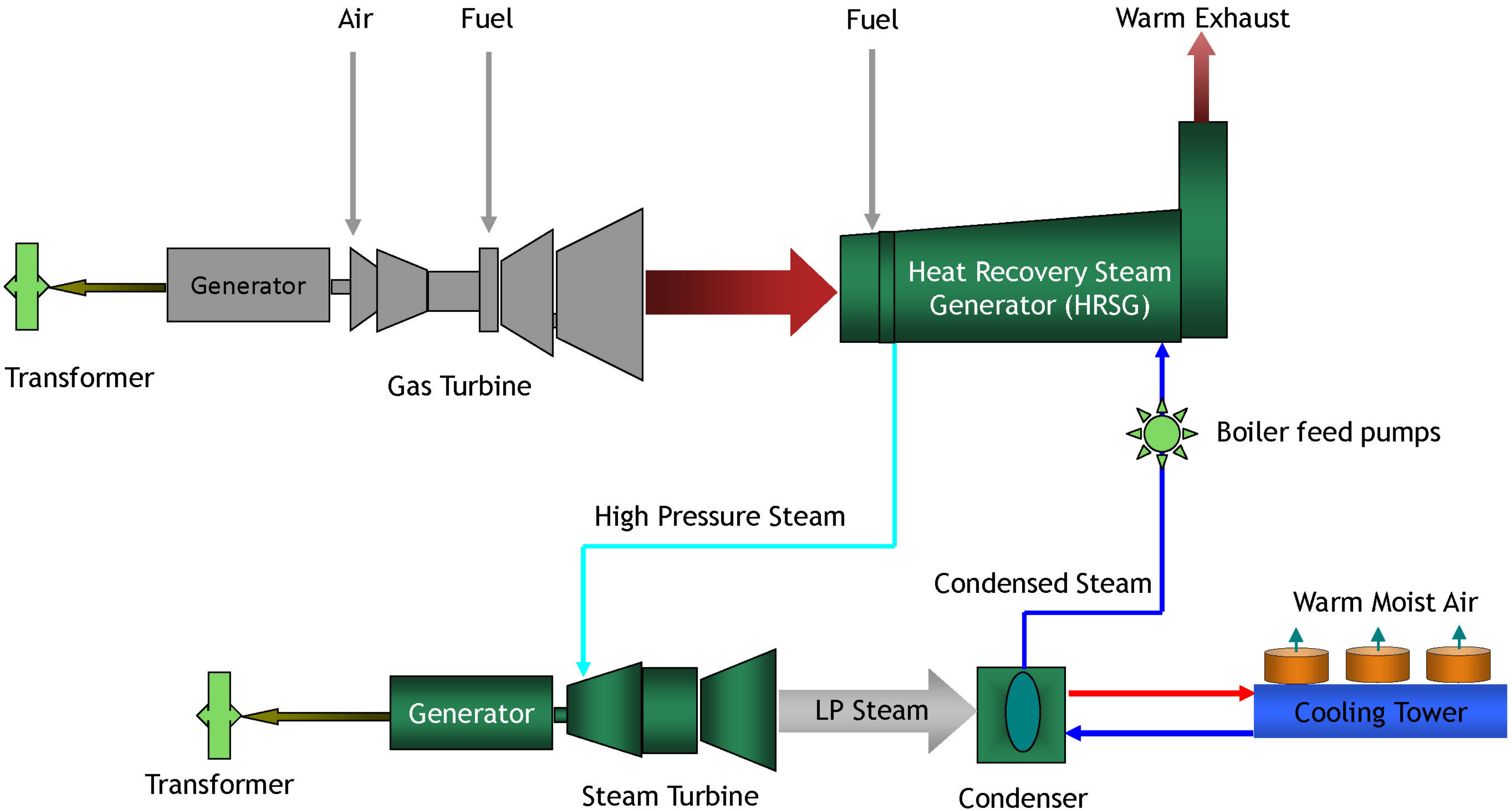
Figures reflect 2021 MW



Combined Cycle Power Plant

Combined Cycle Configuration

Employs more than one thermodynamic cycle (gas and steam turbine) for improved efficiency



Gas Plant Winterization

- Plant personnel health and safety is one of our core values.
- Winter weather can present operational issues with sensitive instrumentation and critical equipment at a combined cycle power plant.
- Operational challenges can exist with, among other things:
  - Process Instrumentation (e.g., drum level transmitters, pressure transmitters)
  - Air system dew points / valve and actuator operations
  - Ammonia systems (for plants with selective catalytic reduction systems [SCRs])
  - Water and steam systems
  - Steam drains
  - Lube Oil System
  - Cooling Water and Cooling Towers
  - Makeup Water Intake Debris Screens
  - Gas regulation and pressure control
- Winterization of combined cycle and simple cycle generation facilities should consider a number of factors, including among other things, the region in which the plant is located, the physical orientation of the facility, design of the facility, age of the facility and the experience of the facility in prior weather events.
  - There is no one-size fits all solution with respect to winterization.
  - The comments contained herein reflect information gathered from the industry generally and do not represent the only winterization strategies available. Each operator must individually evaluate its own facilities when establishing winterization plans.

Winter Readiness Preparation Sample Timeline

Winter Readiness Plans begin well in advance of the Winter:

1. Post-Winter meeting to review issues and incorporate lessons learned into the Winter Readiness Plan and the Winter Operations Procedures **(March-April)**.
2. Initial Site-Specific Pre-Winter Readiness Meetings **(May - July)**:
   – Review the implementation of the Plant Winter Readiness Plan and plan work
3. Final work scope and winterization work plan is in place **(August - September)**.
4. Site-Specific Winter Operation Procedures reviewed and updated based on lessons learned, equipment additions, and any new industrial best practices **(October)**.
5. Complete training on Winter Readiness for plant personnel **(November)**.
6. Site-Specific Pre-Winter Readiness Reviews and Certification of Readiness (**typically November**).
7. Winter Preparations, including training completed by **December** 1.

Sample Winter Readiness Preparations

1. Document the minimum plant design operating temperature to determine the lowest ambient temperature at which the unit can reliably operate.
2. Review any modifications performed to the plant over the past year to assure these modifications meet the minimum plant design operating temperature, or if different, document the minimum temperature limitations of these modifications.
3. Review of the past winter's issues and experience with any equipment freezing.
4. Identify the critical equipment that may be impacted by cold weather.
5. Identify what type of heat tracing is used for the critical equipment, and develop and perform annual preventative maintenance for the heat tracing systems prior to winter.
7. Document the maintenance performed on the instrument air system: how moisture is removed; what is the design dew point; how dew point is monitored.
8. Perform a walkdown of the Critical Equipment's insulation and identify areas of insulation that should be considered for repairs prior to winter operation.
9. Check inventory of necessary consumables and supplies.

Sample Winter Readiness Preparations

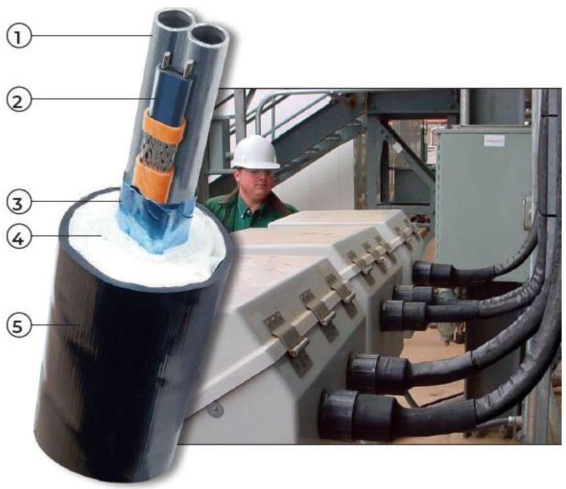
10. Test portable heaters and equipment in storage; check all space heaters.
11. Test permanent building space heaters.
12. Test Heat Tracing Systems.
13. Check glycol concentration in all closed loop cooling water systems to ensure that the fluid freezing point is at or below the site minimum design temperature.
14. Prepare for install of temporary wind breaks and place temporary heaters.
    - If tarps are used, make sure heavy duty material that will last for the entire winter period.
    - Good practice to include a map showing the location of temporary tarps in the winterization plan.
18. Repair any leaks on outside critical components that may be subject to freezing.
19. Prepare critical staffing plans, including evaluation of need for additional staffing.

Sample Critical Equipment Winterization

- Heat tracing of all systems prone to freezing, including chemical addition system.
- Drain certain equipment prior to winter operation.
- Prepare for icing prevention of combustion turbine inlet and air duct/compressors, including adding additional equipment (where applicable) and developing operational prevention methods.
- Build enclosures/wind breaks around certain equipment.
- Set water sample points to be set to continuous drip to prevent freezing.
- Install supplemental heating on sensitive equipment, instruments, etc.
- Address other critical equipment with proper winterization (e.g., vendor supplied chemical storage totes are not heat traced, etc.)
- Winterize temperature sensitive processes (e.g., water treatment chemicals, caustic soda piping, etc.)

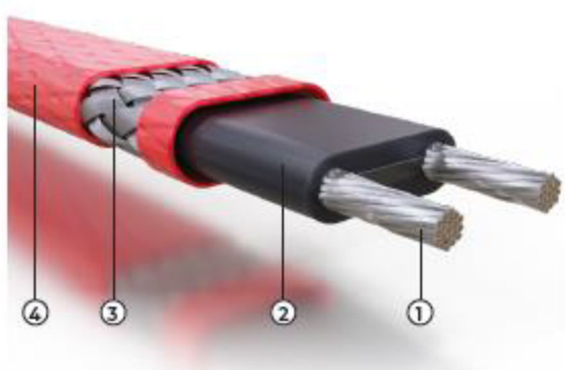
Examples - Heat Tracing

Heat Tracing Components



CONSTRUCTION
1 Process tube(s)
2 USX self-regulating electrical heat tracing
3 Heat reflective tape
4 Non-hygroscopic glass fiber insulation
5 Polymer outer jacket (ATP or TPU available)

Image source: Thermon Group



CONSTRUCTION
1 Nickel-plated copper bus wires (16 AWG)
2 Monolithic co-extruded semiconductive heating matrix and fluoropolymer dielectric insulation
3 Nickel-plated copper braid
4 Fluoropolymer overjacket provides additional protection where exposure to chemicals or corrosives is expected.

Image source: Thermon Group

Examples - Wind Breaks & Enclosures

Examples - Heated Instrument Enclosures

O'Brien Box (Instrument Enclosure)

Questions?

Renewable Generation Weatherization

Kirk Crews, VP – Business Management
Mark Lemasney, VP – Power Generation Division

August 12, 2021

NextEra Energy Resources LLC (NextEra) operates over ~25 GW of wind, solar and battery storage

Background and Agenda

NextEra Operating Portfolio

- **NextEra is world leader in electricity generated from the wind and sun**
  - ~18 GW wind
  - ~4 GW solar
  - ~3 GW battery storage, including backlog
- **NextEra began investing in Texas in 1999**
  - ~4 GW wind
  - ~145 MW solar
  - ~30 MW battery

Topics for Today's Meeting

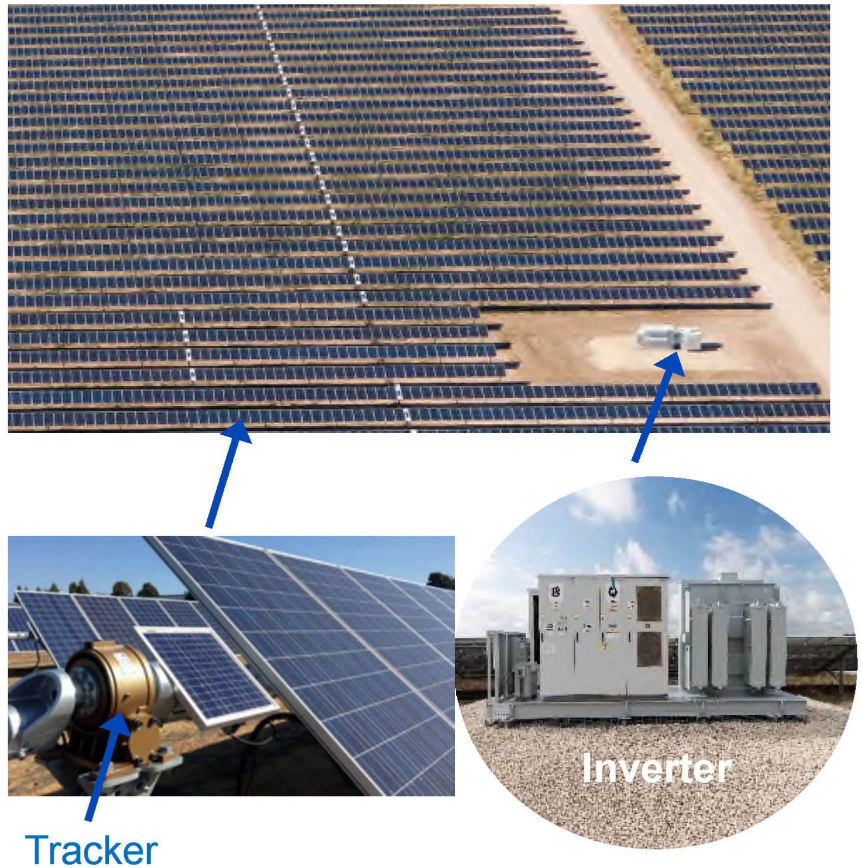
- **Solar PV Weatherization**
- **Battery Weatherization**
- **Wind Weatherization**
  - Turbine Overview
  - Operating in cold and hot temperatures
  - Icing

Solar PV electronic equipment is stored in cabinets with HVAC systems to protect it from the elements, allowing operation in a wide ranges of ambient conditions

Solar PV Overview and Weatherization

- **PV panels convert sunlight to DC power**
  - Panels have no practical temperature limits
  - Snow will block production but can be shed by trackers
  - Trackers will stow in high winds (~45 mph to 90 mph) to protect the panels
- **Inverters convert DC to AC power**
  - Inverter electronics operate between -4° to 122° F

– **Solar projects are capable of operating through Texas' weather patterns, with the only limitation being snow accumulation on panels**

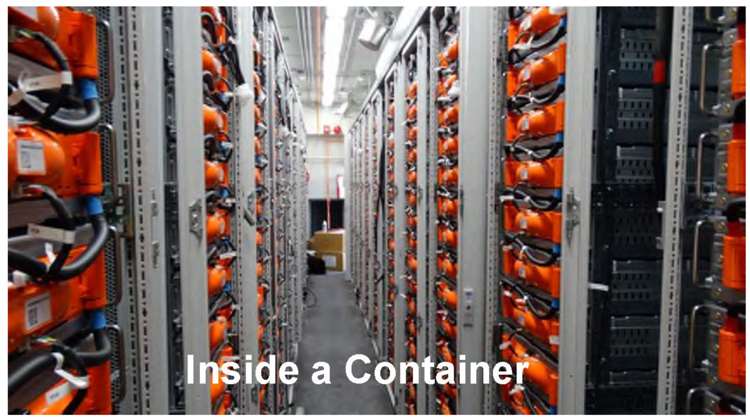


NEXTera ENERGY RESOURCES

Battery Storage Systems have all equipment housed and protected in containers with conditions maintained by HVAC systems

Battery Storage Overview and Weatherization

- **Batteries are housed in controlled environments**
- **Energy from the power grid or from a renewable energy source is delivered to the batteries and then returned to the grid on demand**
  - A battery management system monitors the individual cells and controls the voltage, temperature and current
  - Like Solar PV, battery storage uses inverters to convert DC to AC power
- **While HVAC systems may vary, they typically operate between -4° to 120° F**
- **Battery storage projects are capable of operating through Texas' weather patterns**

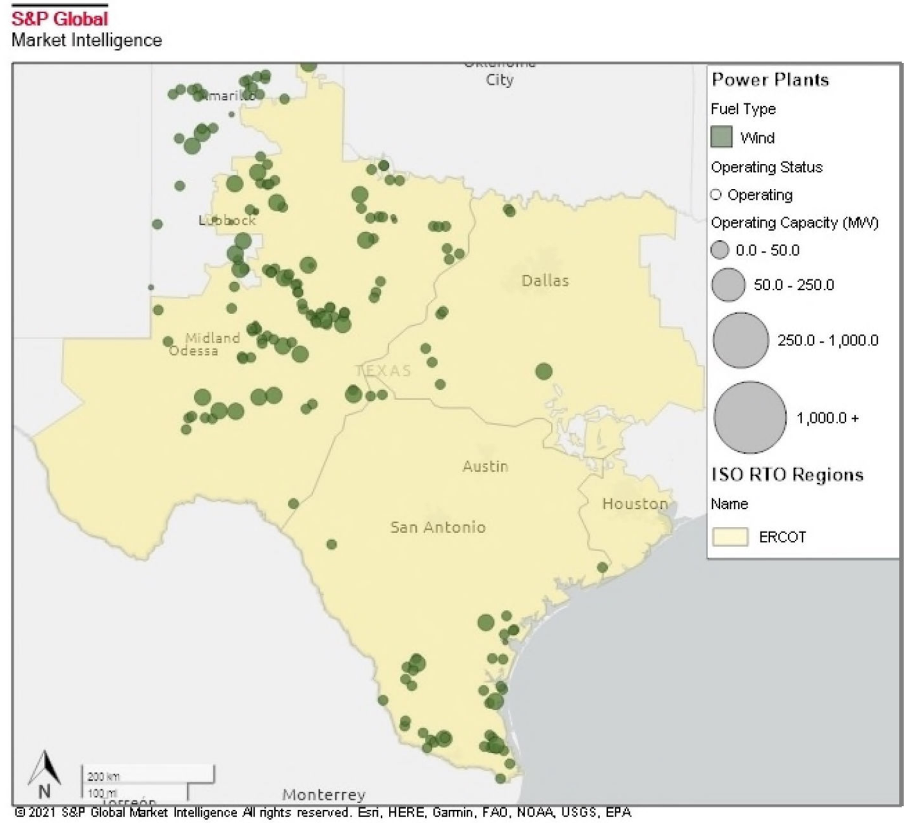


Texas is a proven leader in wind energy

ERCOT Wind Market

- **Over 27 GW of wind capacity installed as of July 31, 2021[1]**
  - Wide range of technologies and vintages ranging from 22 years old (built in 1999) to brand new
    - -- Nearly 40% of the market is more than 10 years old
  - Geographic diversity between North, West, and South Texas
- **GE and NextEra represent a meaningful portion of the market**
  - GE turbines represent ~43% of ERCOT wind
  - NextEra owns and operates ~13% of ERCOT wind

ERCOT Installed Wind Capacity[2]

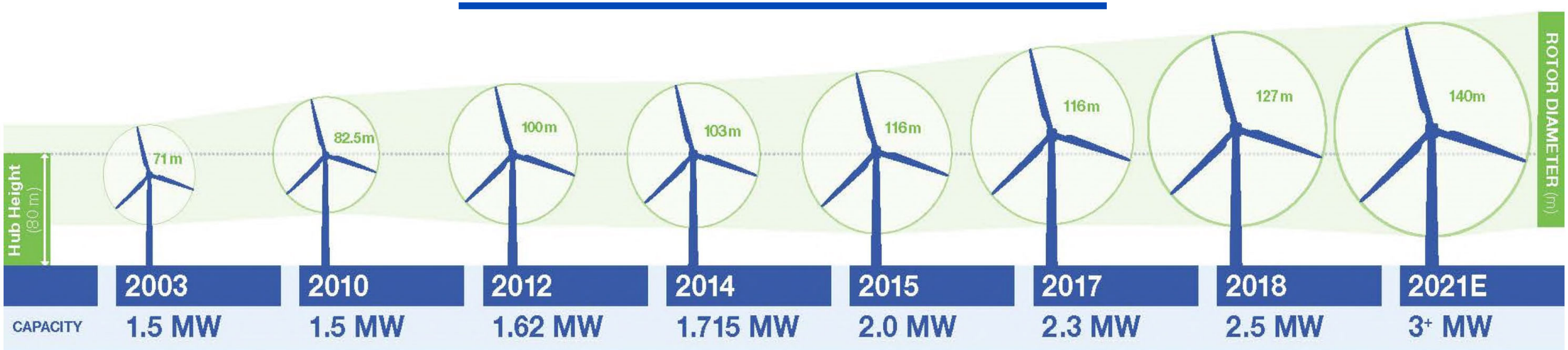


1) Source: ERCOT's Capacity Changes by Fuel Type report and Summer 2021 Seasonal Assessment of Resource Adequacy
2) S&P Global Market Intelligence map tool

NEXTera ENERGY RESOURCES

Wind Turbines have scaled in size significantly over the years covering more swept area to increase the power produced

Wind Turbine Evolution

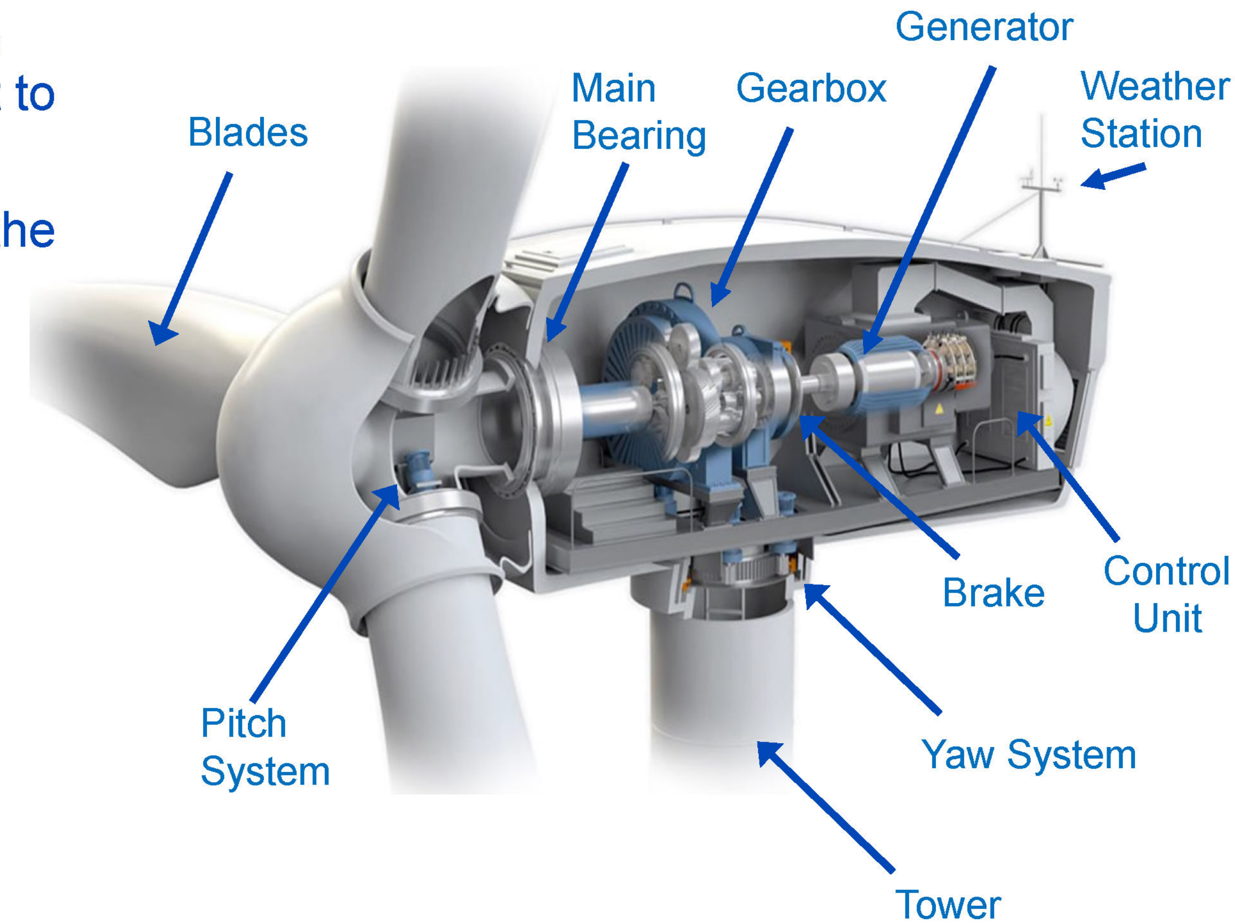


- **Today, a typical 2 to 3 MW turbine costs approx. $2-$3 MM, and will generate electricity with wind speeds between 8 and 56 mph**
  - Above 56 mph Turbines begin to derate to protect equipment
- **Turbines are sited out of flood plains in locations to capture the best wind resource**

NextEra's Wind Turbine fleet in Texas range from 0.7MW with 47-meter rotor diameter to 2.8MW with 127-meter rotor diameter

Wind Turbine Overview

- Wind turbine blades capture kinetic energy and convert it to rotating mechanical energy
- The main bearing supports the blades and rotor (shaft) and transmits torque to the gearbox
- The gearbox transmits low speed shaft power to high speed for the generator
- The generator converts the mechanical energy from the gearbox to electrical energy
- Electrical energy is then transmitted down-tower and travels through a collection system, transformers and a substation where the voltage is boosted for delivery onto the grid



Texas PUC Work Session

August 12, 2021
Daniel Hynum
Senior Product Manager
GE Renewable Energy

Building a world that works

Operating in Cold and Hot Temperatures

GE standard turbine operates between 5°-104°F

GE offers various solutions in the United States to allow turbines to operate in extreme cold temperatures

- Winter Ice Operation Mode
- Cold Weather Extreme Package

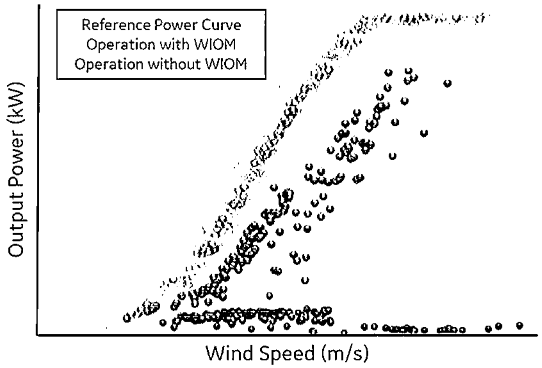
Icephobic coatings are not a proven technology for wind turbines and there is currently no GE offering

Heated blade solutions for new units are not currently offered in the United States

Building a world that works

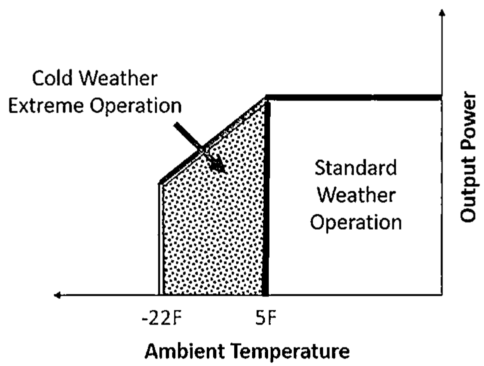
Extreme Cold Solution Offerings

Winter Iced Operation Mode



- **Controls solution to detect ice accretion and adjust pitch to accommodate**
  - Highly effective with rime ice
  - Less effective with glaze ice
  - Does not remove ice
  - Globally available today for GE turbines
  - Can be retrofitted

Cold Weather Extreme Package



- **Allows turbines to extend operations from 5°F to - 22°F**
  - Used in extreme cold temperature locations
  - Globally available today for GE turbines
  - Retrofit dependent on tower steel

- **Key components at extreme cold ambient temperatures**
  - Tower Steel
  - Electronics
  - Lubrication

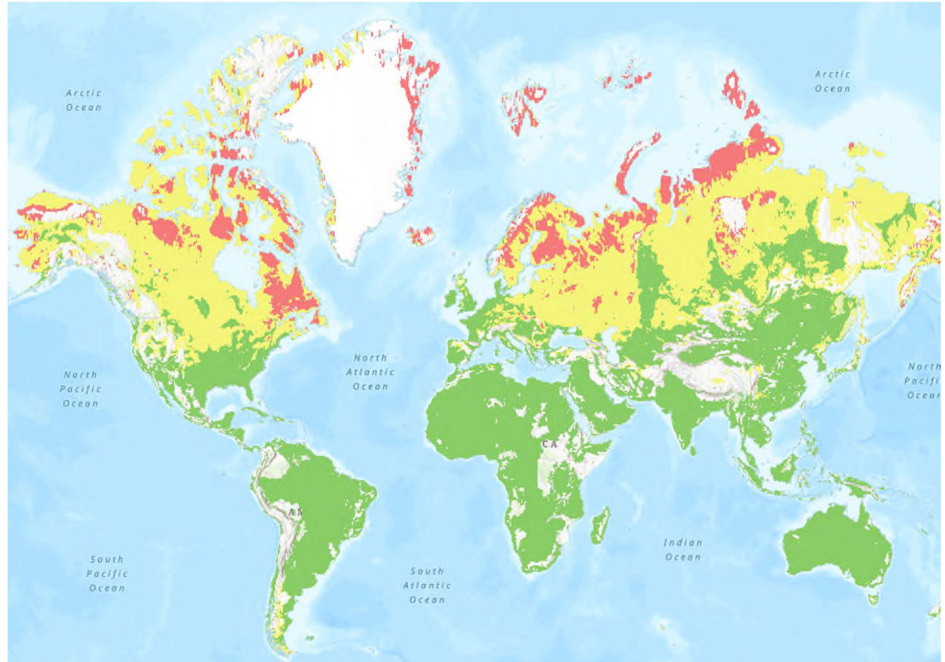
Building a world that works

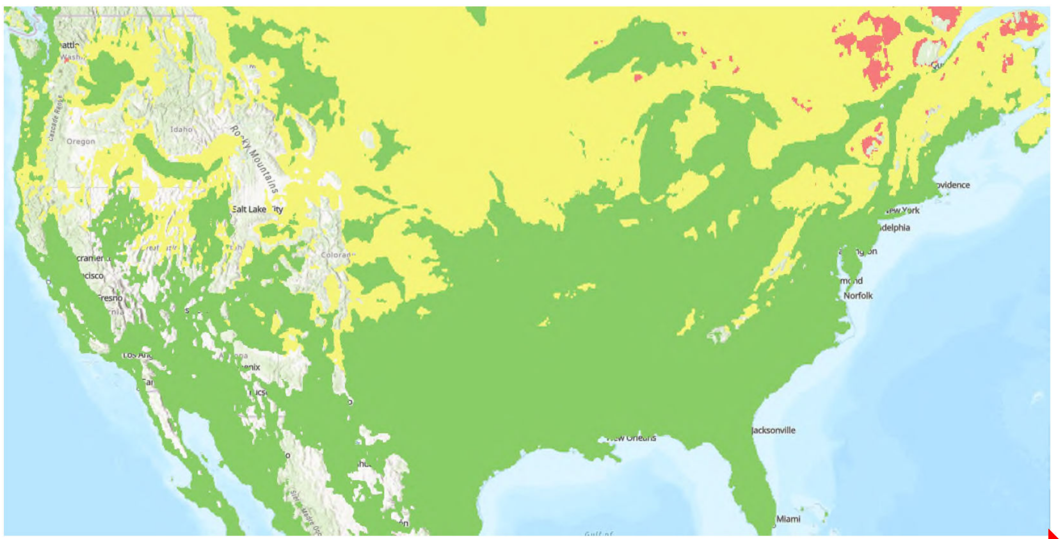
Understanding IEA Ice Classification

International Energy Agency (IEA) informs the weatherization solutions offered in each region of the world

Heated blade solutions are not currently offered in the US

Texas is Class 1 along with most of US





IEA Ice Class	Duration of meteorological icing [days]	Production loss [% of Annual Energy Production]
5	>36	>20%
4	18-36	10-25%
3	11-18	3-12%
2	2-11	0.5-5%
1	0-2	<0.5%

Texas

Source: International Energy Agency

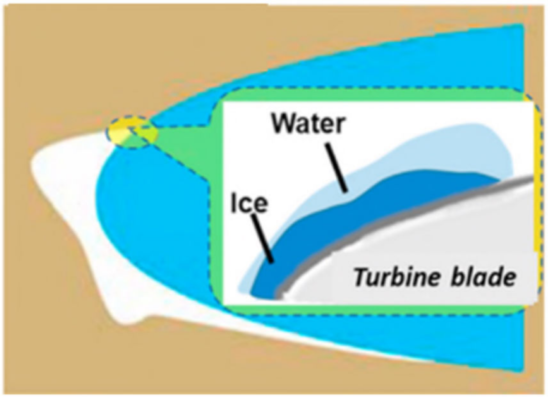
Blade Icing

32F

14F

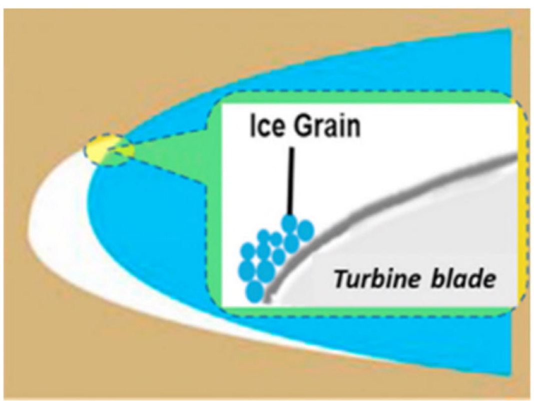
-4F

Glaze Ice



- **Caused by warm air/humidity mixing with precipitation**
  - Occurs at temperatures just below freezing
  - High surface adhesion
  - Heavier ice build up
  - Significant impact to performance

Rime Ice



- **Caused by extreme cold temperatures with low humidity**
  - Occurs at temperatures well below freezing
  - Low surface adhesion
  - Light ice build up
  - Minor impact to performance

Building a world that works

Source: Hui, Iowa State University

Summary

Texas is an IEA Class 1 state, and thus experiences 0-2 days of icing per year

GE offers Winter Ice Operation Mode (WIOM) and Cold Weather Extreme (CWE) packages, which are available today for new turbine orders

- WIOM can be retrofitted on existing turbines
- CWE can also be added, with some limitations

The current GE technology road map does not include heated blade solutions for the United States

NERC Winter Weatherization Activities

Joseph P. Younger,

Director, Enforcement, Reliability Standards, and Registration

Winterization Activities Prior to the Mandatory Cold Weather Standard

February 2011 Winter Weather Event

- Texas RE supported FERC and NERC efforts to review and develop recommendations following the February 2011 Cold Weather Event

FERC/NERC Staff Report on the 2011 Southwest Cold Weather Event

- The report provided winter weatherization recommendations for generator owners/operators on plant design, maintenance and inspections, and implementation of specific freeze protection measures

Based on these recommendations, NERC issued voluntary Reliability Guidelines and Lessons Learned on generator winter preparations

- NERC's guidelines on generator winter preparation

Texas RE's Engagements Around Winterization Activities

Texas RE has focused on distributing key practices and information on cold weather reliability and resilience activities through:

- Conducting annual generator preparedness workshops since 2013
  - Centers on information sharing around challenges and best practices
- Performing focused site visits to review generator weatherization preparations and share best practices
  - Over the past three years, Texas RE and ERCOT staff have conducted 134 facility site visits

Project 2019-06 – Mandatory Cold Weather Preparedness Requirements

Project reviews and addresses Cold Weather Preparedness recommendations from the 2019 Report - South Central United States Cold Weather Bulk Electric System Event of January 17, 2018

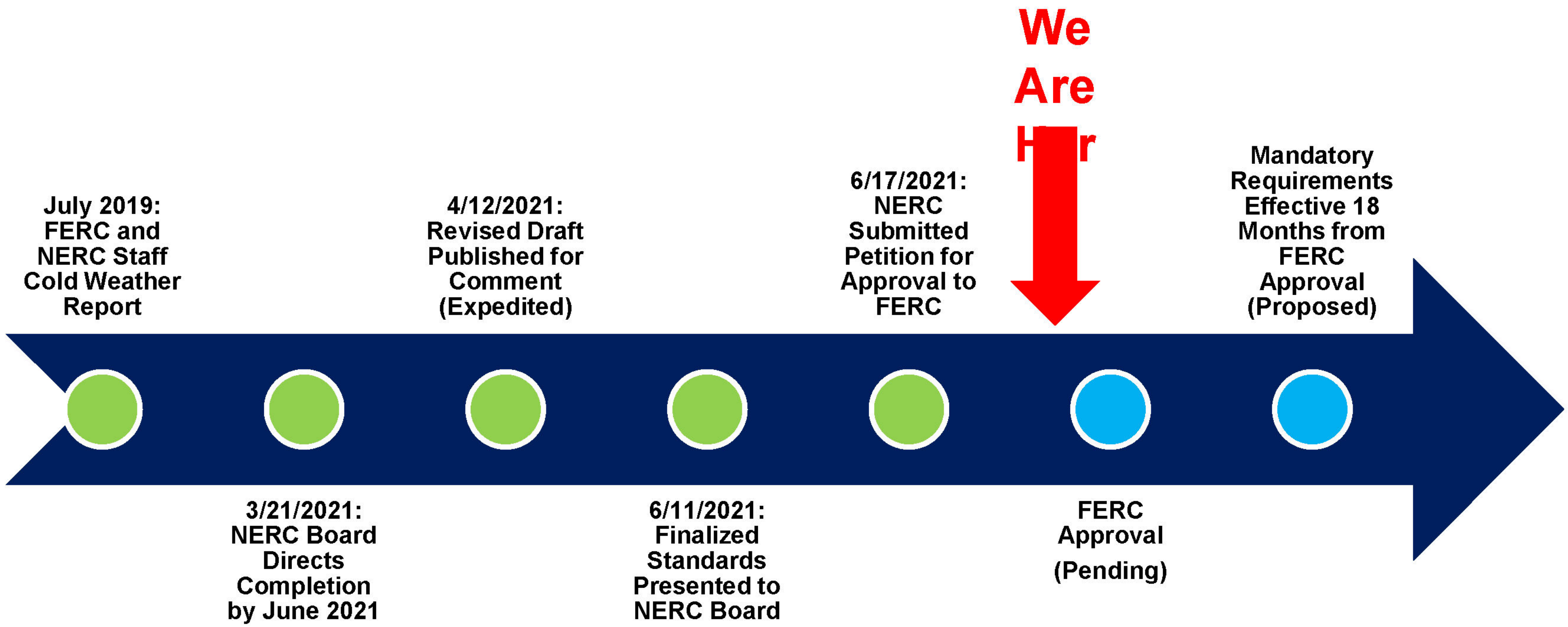
Project focused on two core areas in connection with Cold Weather Preparedness:

- Requirements for GOs to develop and implement cold weather preparedness plan(s) for its generating units
- Provisions for notification through documented data specifications of generating unit status during forecasted cold weather

Cold Weather Preparedness Plan Requirements

- Implement “freeze protection measures” based on geographic location and plant configuration
- Perform annual maintenance and inspection activities on the freeze protection measures
- Develop data on operating limitations
- Provide unit-specific training to personnel

Project 2019-06 Cold Weather: Timeline



Texas RE is supporting NERC and FERC's Joint Inquiry reviewing of events in Texas and the South Central United States

- Initial findings in anticipated in September
- Final report in November

Planned Texas RE Winterization Activities

Outreach Activities

- Overview of the Cold Weather Standards held on July 8, 2021
- Targeted outreach with Generation Owners to discuss winterization preparations on August 23, 2021
- Annual Winter Weatherization Workshop on September 30, 2021
- Future outreach regarding Joint Inquiry findings, lessons learned, and best practices identified
- Targeted outreach with key stakeholders to discuss ongoing preparations, key focus areas, and implementation challenges

Support Development of Possible Enhancements to the NERC Cold Weather Standard based on FERC Directives or Recommendations

Support for NERC and Industry's efforts to develop Compliance Guidance to Implement the Cold Weather Standards

Compliance and Enforcement Activities as appropriate

Questions?

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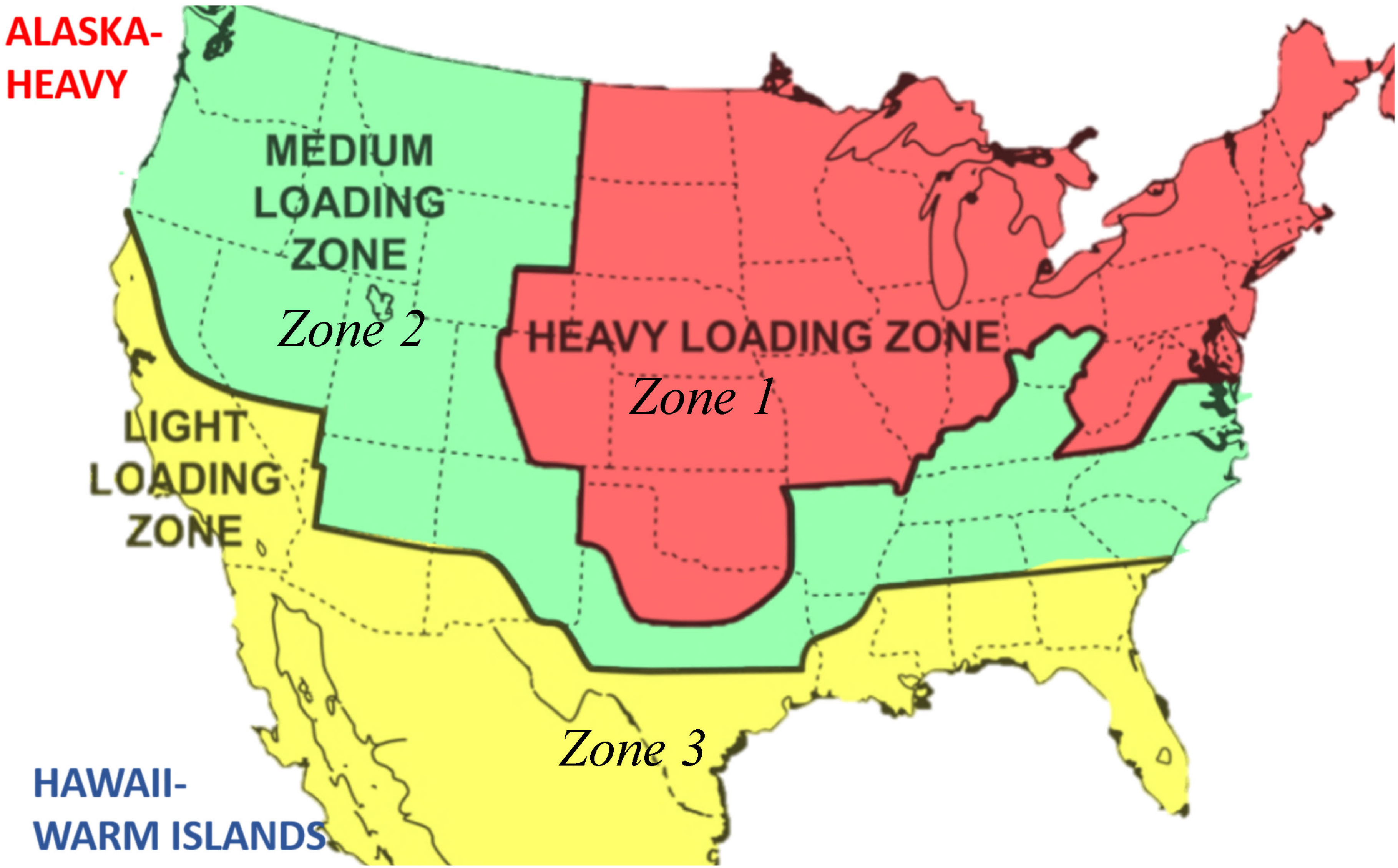
Weather Rules

National Electric Safety Code (NESC)

IEEE Standard C2-2017

Standard developed by IEEE's National Electric Safety Committee using procedures approved by the American National Standards Institute (ANSI)

Clearance and Loading Zone Map
Combination of Figures 230-1 and 250-1 of the NESC



Map Notes

Clearance Zones 1, 2, and 3 determine where specified overhead line conductor clearances apply. (NESC Section 23)

Loading Zones “Heavy”, “Medium”, “Light” and “Warm Islands” determine where specified wind and ice loading of lines apply for analysis. (NESC Section 25)

Texas falls within Zones 1 through 3: Heavy, Medium and Light Loading.

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Weather Characteristics in Clearance Rules

Section 23: Rule 230B. Ice and wind loading for clearances

Defines minimum ice, wind speed and temperature characteristics for each zone that must be considered in the design when calculating expected conductor sag and blowout and the subsequent clearances above ground, structures, other circuits, communications cables, roads and other facilities.

Ice buildup applies weight to the conductor which elongates conductors.

Ice and wind combine to apply horizontal forces on the conductor, which cause blowout, the displacement from the “at rest” conductor position.

Ice, wind and temperature characteristics affect the short- and long-term deformation, or stretching, of conductors which impacts sags and clearances.

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Table 230-1—Ice thickness for purposes of calculating clearances

	Clearance zone (for use with Rules 232, 233, 234, and 235)				
	Zone 1 see Figure 230-1	Zone 2 see Figure 230-1	Zone 3 see Figure 230-1	Zone 4: Warm islands ①	
				Altitudes sea level to 2743 m (9000 ft)	Altitudes above 2743 m (9000 ft)
Radial thickness of ice					
(mm)	12.5	6.5	0	0	6.5
(in)	0.50	0.25	0	0	0.25

① Warm islands are those located from latitude 25 degrees south through 25 degrees north and include American Samoa (14°S), Guam (13°N), Hawaii (22°N), Puerto Rico (18°N), and Virgin Islands (18°N).

The ice is assumed to surround the conductor at uniform thickness. For example, in Zone 1, the ½-inch of ice thickness adds 1 inch to the diameter of the ice/conductor cross section.

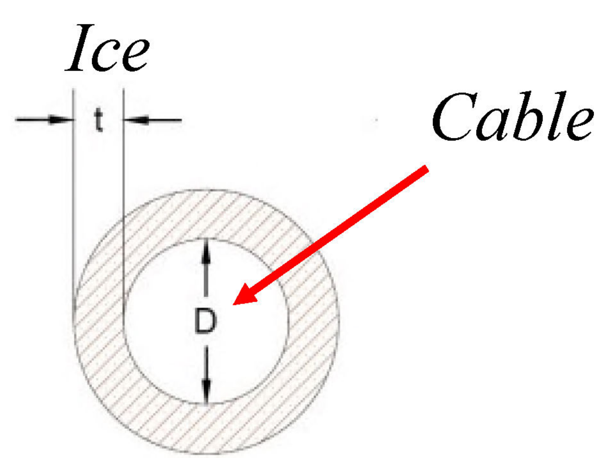

Table 230-2—Ice, wind pressures, temperatures, and additive constants for purposes of calculating final inelastic deformation

Zone

Ice

Wind

Temp

	Clearance zone (for use with Rules 232, 233, 234, and 235)				
	Zone 1 Heavy ice: see Figure 230-1	Zone 2 Moderate ice: see Figure 230-1	Zone 3 Little or no ice: see Figure 230-1	Zone 4: Warm islands [1]	
				Altitudes sea level to 2743 m (9000 ft)	Altitudes above 2743 m (9000 ft)
Radial thickness of ice					
(mm)	12.5	6.5	0	0	6.5
(in)	0.50	0.25	0	0	0.25
Horizontal wind pressure					
(Pa)	190	190	430	430	190
(lb/ft^2)	4	4	9	9	4
Temperature					
(°C)	–20	–10	–1	+10	–10
(°F)	0	+15	+30	+50	+15
Constant to be added to the resultant [2]					
(N/m)	4.40	2.90	0.73	0.73	2.90
(lb/ft)	0.30	0.20	0.05	0.05	0.20

[1] Warm islands are those located from latitude 25 degrees south through 25 degrees north and include American Samoa (14°S), Guam (13°N), Hawaii (22°N), Puerto Rico (18°N), and Virgin Islands (18°N).

[2] For cable arrangements supported by a messenger using spacers or rings and where each conductor or cable is separately loaded with ice and wind as described in Rule 230B3c(2) [as opposed to being analyzed with the ice and wind applied to a hollow cylinder touching the outer strands of the conductors as described in Rule 230B3c(1)], the constant specified here shall be added to the resultant load of each component conductor and the messenger.

Table 250-4—Wind speed conversions to pressure

To be used only with the extreme ice with concurrent wind loading of Rule 250D and Figure 250-3.

Wind speed (mph)	Horizontal wind pressure	
	Pascals	lb/ft^2
30	110	2.3
40	190	4.0
50	310	6.4
60	440	9.2
70	600	12.5
80	780	16.4

The force of wind on cylindrical shapes such as conductor, poles and insulators is approximately:

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$F\ (lbs/ft^2) = 0.00256\ (v)^2$ where v is the wind velocity in mph

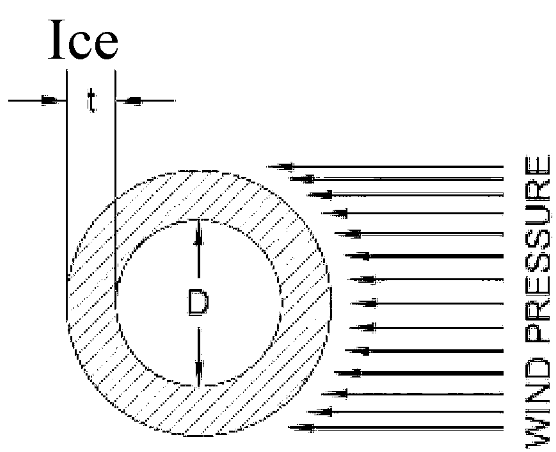
Weather Characteristics in Loading Rules

Section 25:

The NESC defines three loading scenarios that address the ice, wind and temperature characteristics to be used to determine the strength of structures and conductors in the design phase. The rule that requires the greatest strength controls the design decisions.

- Rule 250B. Combined ice and wind district loading
- Rule 250C. Extreme wind loading
- Rule 250D. Extreme ice with concurrent wind loading

The characteristics differ by location according to the Heavy, Medium and Light loading zones.



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Rule 250B

Table 250-1—Ice, wind pressures, and temperatures

Zone	Loading districts (for use with Rule 250B)					Extreme wind loading (for use with Rule 250C)	Extreme ice loading with concurrent wind (for use with Rule 250D)
	Heavy see Figure 250-1	Med-ium see Figure 250-1	Light see Figure 250-1	Warm islands [1]			
				Altitudes sea level to 2743 m (9000 ft)	Altitudes above 2743 m (9000 ft)		
Radial thickness of ice							
(mm)	12.5	6.5	0	0	6.5	0	See Figure 250-3
Ice (in)	0.50	0.25	0	0	0.25	0	See Figure 250-3
Horizontal wind pressure							
(Pa)	190	190	430	430	190	See Figure 250-2	See Figure 250-3
Wind (lb/ft2)	4	4	9	9	4	See Figure 250-2	See Figure 250-3
Temperature							
(°C)	–20	–10	–1	+10	–10	+15	–10
Temp (°F)	0	+15	+30	+50	+15	+60	+15

[1] Warm islands located from latitude 25 degrees south through 25 degrees north include American Samoa (14°S), Guam (13°N), Hawaii (22°N), Puerto Rico (18°N), and Virgin Islands (18°N).

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Rule 250C

Extreme wind loading rule applies to 60-foot and taller structures.

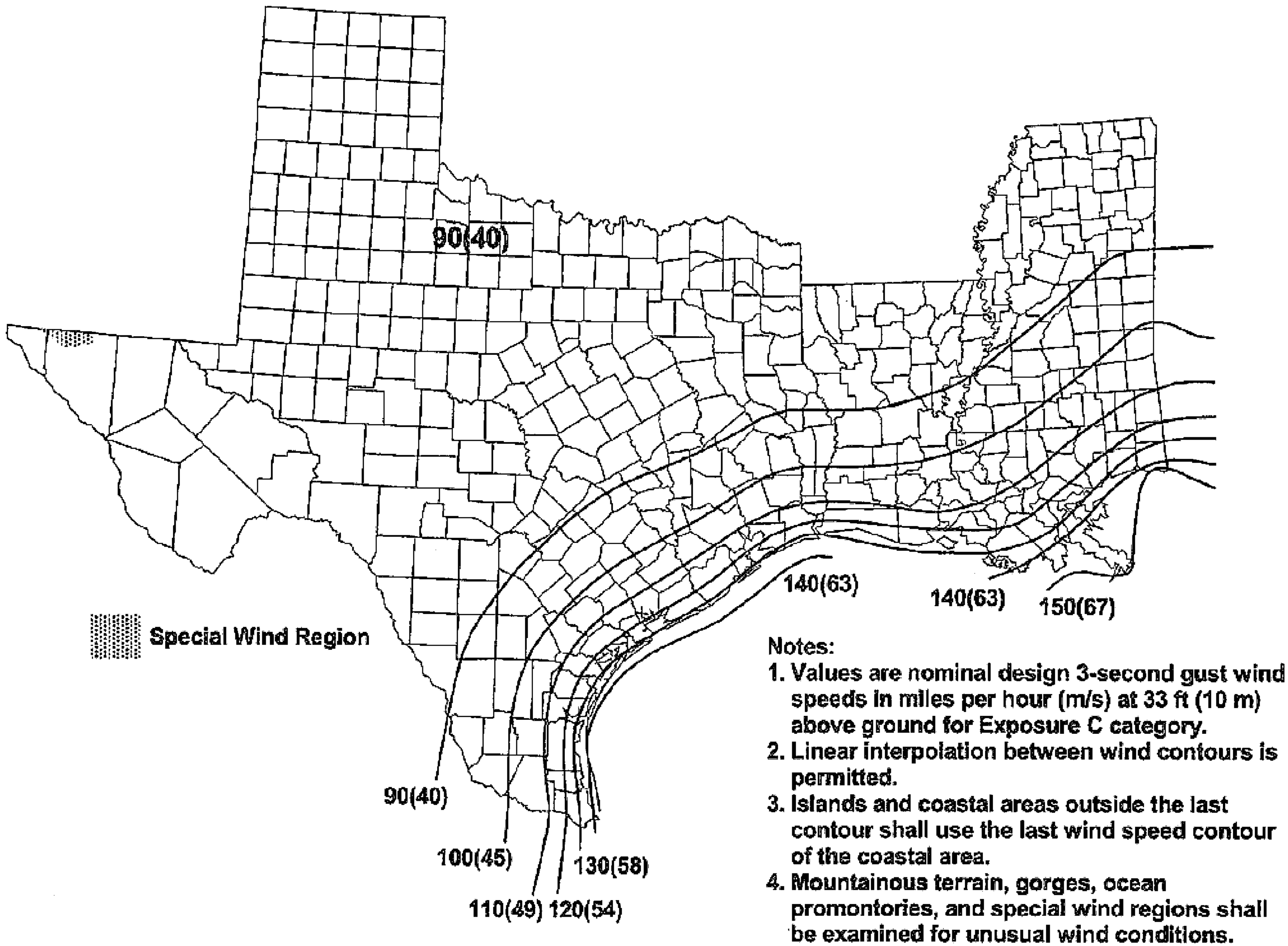

Figure 250-2(c)—Western Gulf of Mexico hurricane coastline

NOTE: Figure 250-2(c) reprinted with permission from ASCE, 1801 Alexander Bell Dr., Reston, VA 20191 from ASCE 74-10, Guidelines for Electrical Transmission Line Structural Loading. Copyright © 2010.

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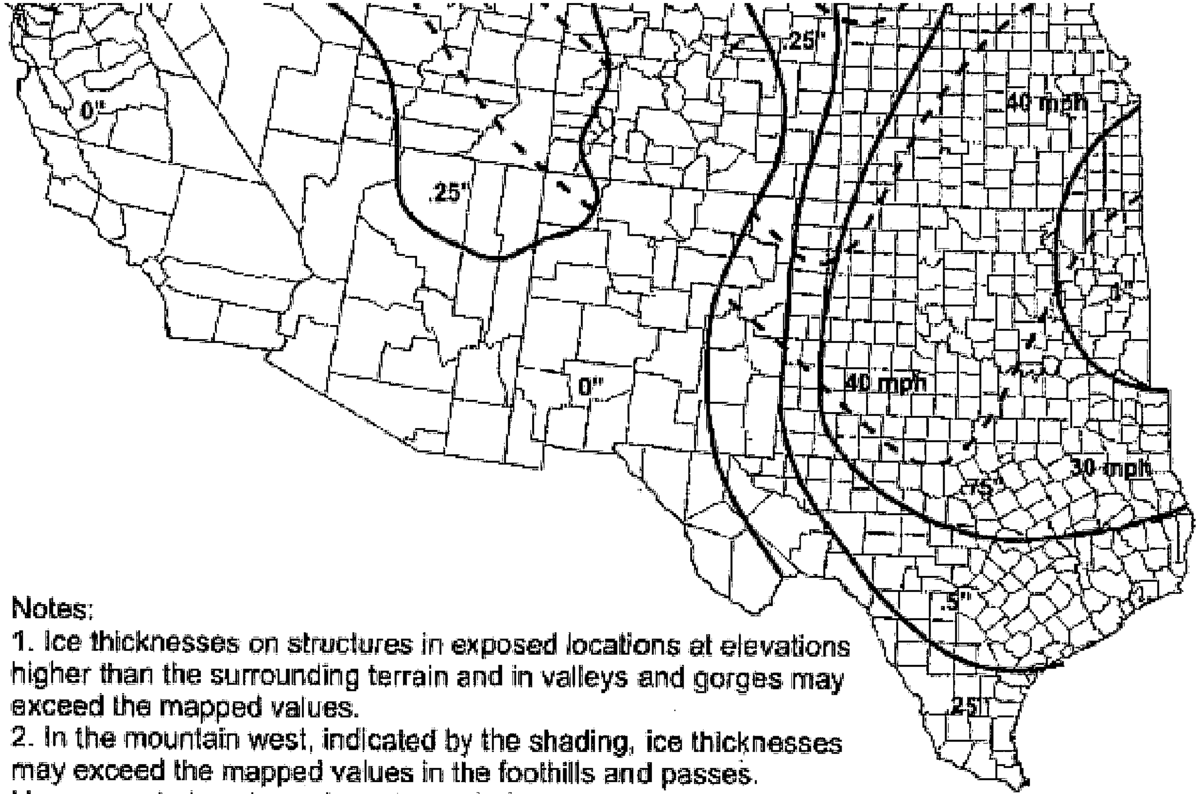
Rule 250D

Extreme wind and ice loading applies to 60-foot and taller structures.



50-YEAR MEAN RECURRENCE INTERVAL UNIFORM ICE THICKNESSES DUE TO FREEZING RAIN WITH CONCURRENT 3-SECOND GUST SPEEDS: CONTIGUOUS 48 STATES.

Figure 250-3(a)—Uniform ice thickness with concurrent wind

NOTE: Figure 250-3(a) reprinted with permission from ASCE, 1801 Alexander Bell Dr., Reston, VA 20191, from ASCE 7-10, Minimum Design Loads for Buildings and Other Structures. Copyright © 2010.

Additional Load Factors

Rule 253

Table 253-1—Load factors for structures[1], crossarms, support hardware[8], guys, foundations, and anchors to be used with the strength factors of Table 261-1

Load Factors			
	Grade B	Grade C	
		At crossings[6]	Elsewhere
Rule 250B loads (Combined ice and wind district loading) Vertical loads[3]	1.50	1.90[5]	1.90[5]
Transverse loads Wind Wire tension	 2.50 1.65[2]	 2.20 1.30[4]	 1.75 1.30[4]
Longitudinal loads In general At deadends	 1.10 1.65[2]	 No requirement 1.30[4]	 No requirement 1.30[4]
Rule 250C loads (Extreme wind) Wind loads All other loads	 1.00 1.00	 0.87[7] 1.00	 0.87[7] 1.00
Rule 250D loads (Extreme ice with concurrent wind)	1.00	1.00	1.00

①Includes pole.
②For guys and anchors associated with structures supporting communication conductors and cables only, this factor may be reduced to 1.33.
③Where vertical loads significantly reduce the stress in a structure member, a vertical load factor of 1.0 should be used for the design of such member. Such member shall be designed for the worst case loading.
④For metal or prestressed concrete, portions of structures, crossarms, guys, foundations, and anchors, use a value of 1.10.
⑤For metal, prestressed concrete, or fiber-reinforced polymer portions of structures and crossarms, guys, foundations, and anchors, use a value of 1.50.
⑥This applies only where a line crosses another supply or communication line (see Rule 241C and Table 242-1).
⑦For wind velocities above 100 mph (except Alaska), a factor of 0.75 may be used.
⑧Support hardware does not include insulators. See Section 27 for insulator strength and loading requirements.

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The NESC addresses additional specific characteristics for designers to consider that impact strength requirements. Characteristics not addressed in this presentation include:

- Grades of construction (B, C and N)
- Altitude differences
- Facilities that cross zone boundaries
- Bundled conductors
- Structure shape coefficients (Flat surfaces vs. cylindrical)
- Special wind regions
- Heights of structures
- Angle and deadend vs. tangent (in-line) structures

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